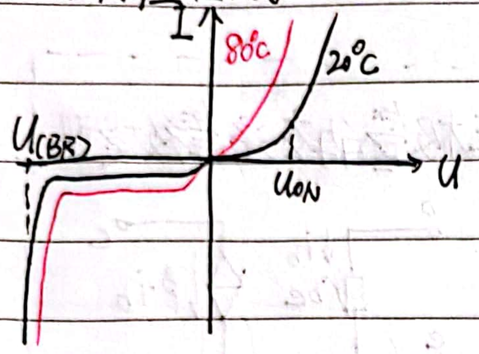
模电期末总结

第一章：常用半导体器件

1.二极管

(1)伏安特性曲线



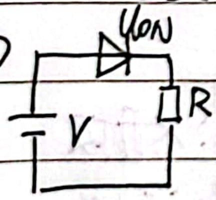
{利用~~正向特性~~单向导通性可用于整流
利用反向特性可用于稳压

(2)重要公式：$i = I_S(e^{\frac{u}{U_T}}-1)$ ☆☆☆

（U_T为温度下的电压当量，常温下，$U_T=26mV$）

(3)二极管的微变等效☆

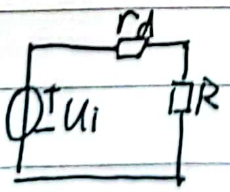
①



$I_D = \frac{V-U_{ON}}{R}$

② $r_d = \frac{U_T}{I_D}$

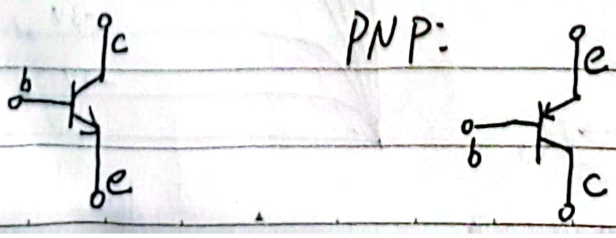
③



$i_d = \frac{u_i}{r_d+R}$

2.三极管

NPN：　PNP：



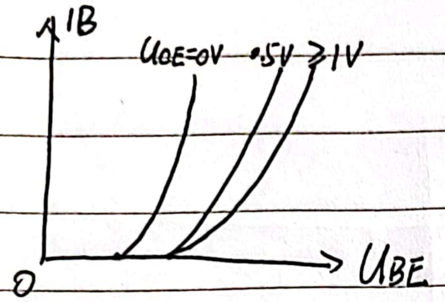
b：基极
c：集电极
e：发射极

(1) 工作状态：截止：发射结反偏，集电结反偏

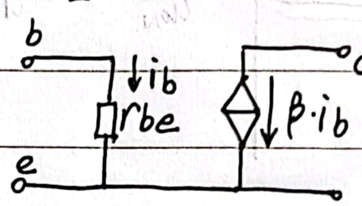
放大：发射结正偏，集电结反偏　$i_B = \beta \cdot i_c$

饱和：发射结正偏，集电结正偏

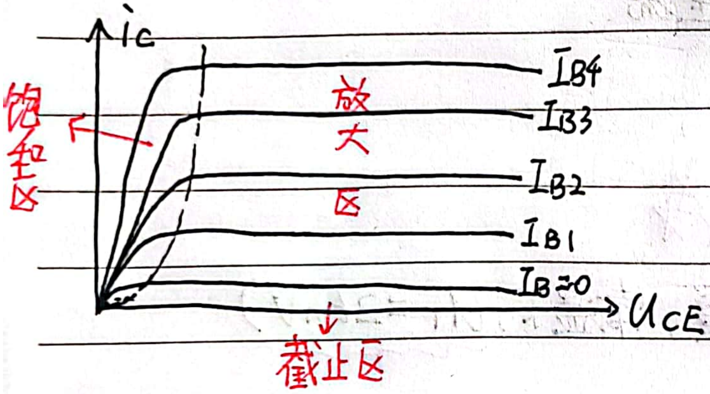
(2) NPN 特性曲线



三极管的交流等效模型



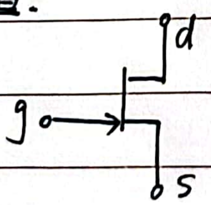
$r_{be} = r_{b'b} + (1+\beta)\cdot\frac{U_T}{I_{EQ}}$



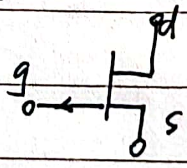
3. 场效应管（了解）

(1) 结型场效应管

N沟道：



P沟道：

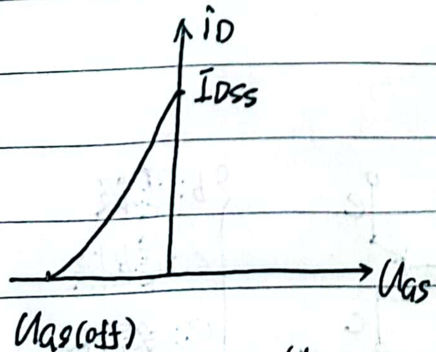


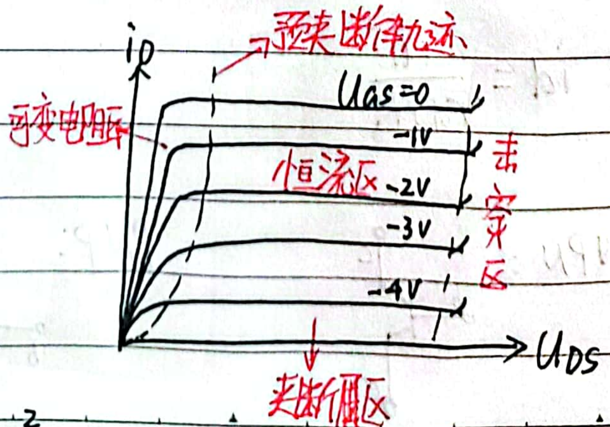
g：栅极

d：漏极

s：源极

(2) 特性曲线（N沟道）



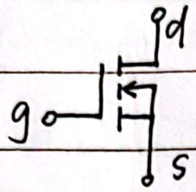


$i_D = I_{DSS}\left(\frac{U_{GS}}{U_{GS(off)}} - 1\right)^2$

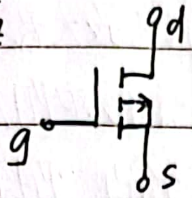
(2) 绝缘栅型场效应管

① 增强型

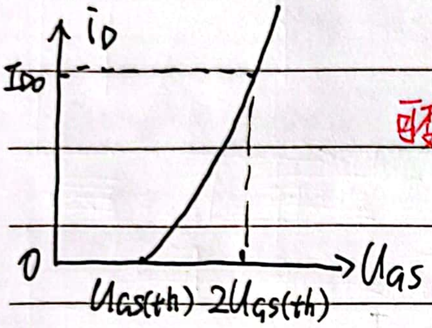
N沟道

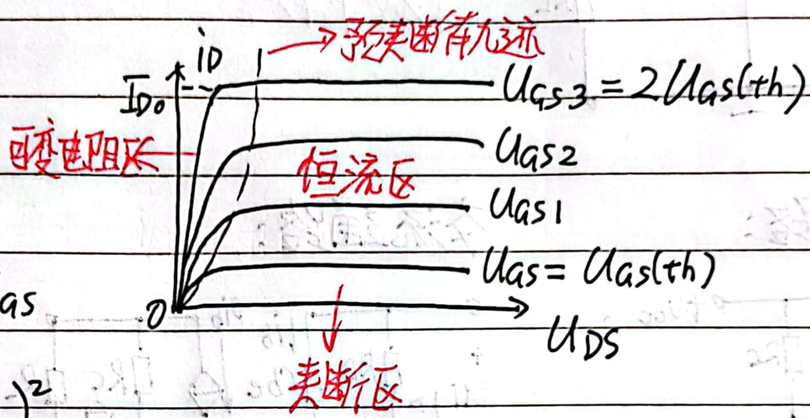


P沟道



特性曲线

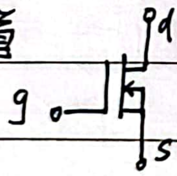




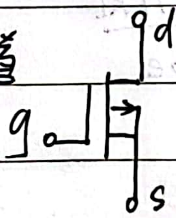
$$i_D = I_{D0}\left(\frac{U_{GS}}{U_{GS(th)}} - 1\right)^2$$

② 耗尽型

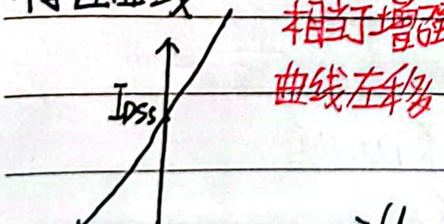
N沟道



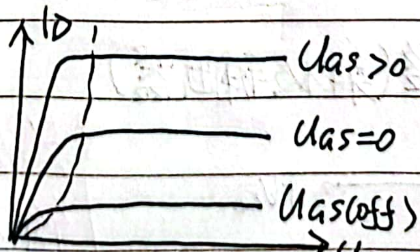
P沟道



特性曲线



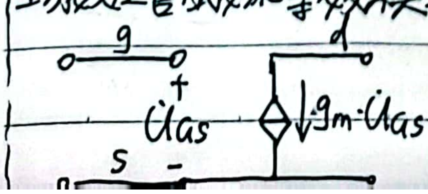
相对于增强型曲线左移



相对于增强型曲线上移

$$i_D = I_{DSS}\left(\frac{U_{GS}}{U_{GS(off)}} - 1\right)^2$$

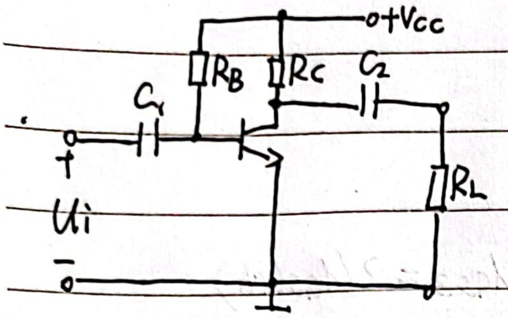
场效应管的交流等效模型 ☆☆



第二章:基本放大电路

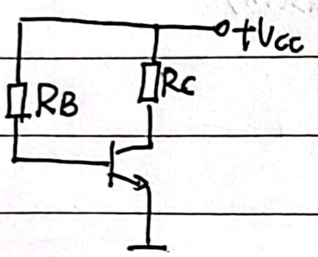
1、几类放大电路 ☆☆☆

①基本共射放大电路

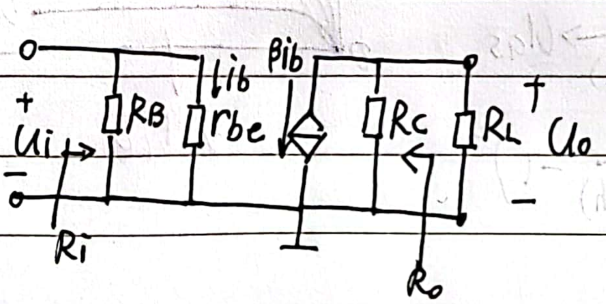


- 既放大电流、又放大电压
- 输入电阻居三种电路之中
- 输出电阻较大
- 频带较窄

直流通路:



交流通路:

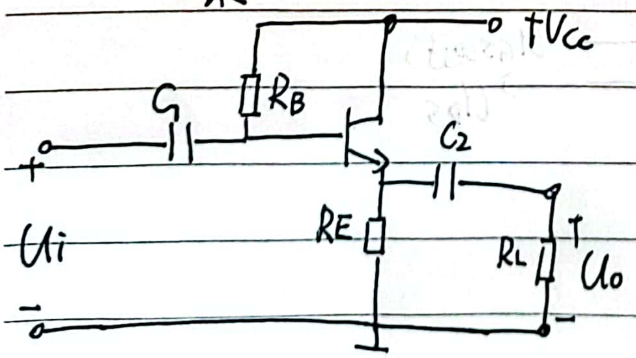


$$A_u = \frac{-\beta \cdot i_b \cdot R_C // R_L}{i_b \cdot r_{be}} = \frac{-\beta \cdot R_C // R_L}{r_{be}}$$

$$R_o = R_C$$

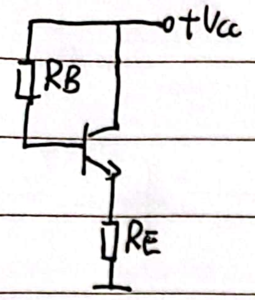
$$R_i = R_B // r_{be}$$

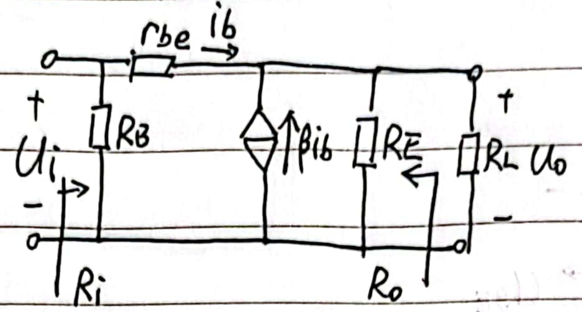
②基本共集放大电路(射极输出器)



- 只放大电流,不放大电压
- 输入电阻最大
- 输出电阻最小

直流通路：　　　　交流通路：



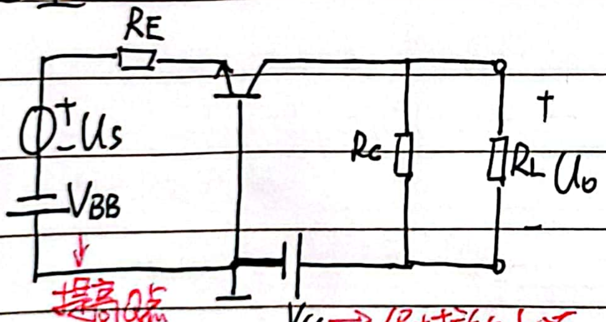


$$A_u=\frac{(1+\beta)i_b\cdot R_E//R_L}{(1+\beta)i_b\cdot R_E//R_L+i_b\cdot r_{be}}=\frac{(1+\beta)R_E//R_L}{(1+\beta)R_E//R_L+r_{be}}<1\ (\text{但趋向于}1)$$

$$R_i=R_B//[r_{be}+(1+\beta)R_E//R_L]$$

$$R_o=R_E//\frac{r_{be}}{1+\beta}$$

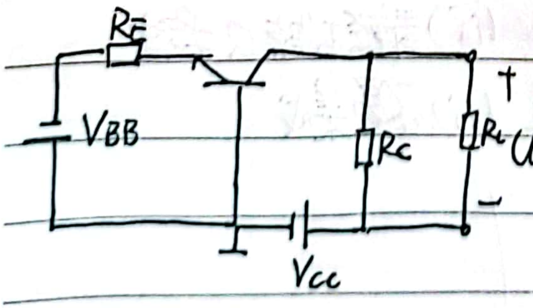
③基本共基放大电路

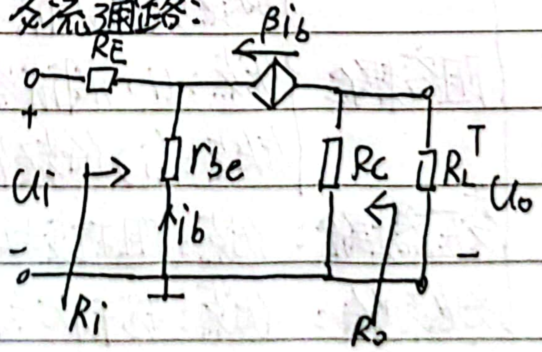


Vcc→保持放大状态

只放大电压，不放大电流
输入电阻小
放大倍数，输出电阻与共射电路相当
通频带最宽

直流通路：　　　　交流通路：





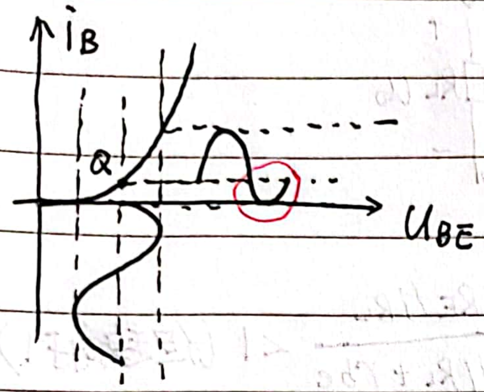
$$A_u=\frac{-\beta i_b\cdot R_C//R_L}{-i_b\cdot r_{be}-(1+\beta)i_b\cdot R_E}=\frac{\beta R_C//R_L}{r_{be}+(1+\beta)R_E}$$

$$R_i=R_E+\frac{r_{be}}{1+\beta}$$

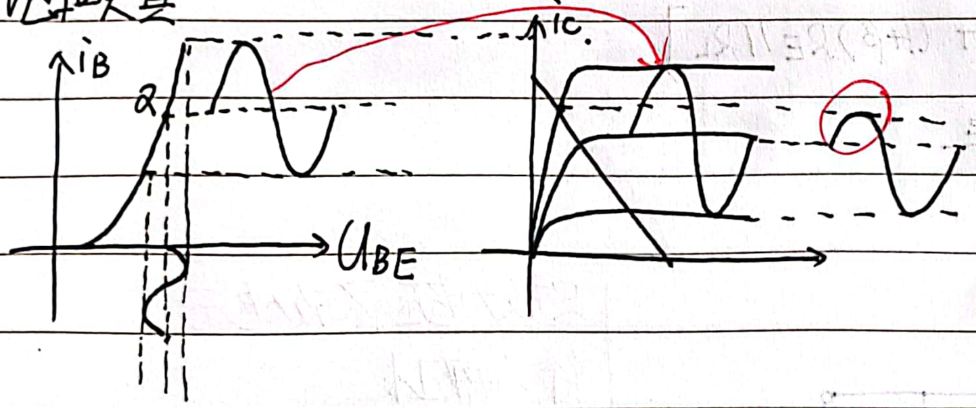
$$R_o=R_C$$

2. 截止失真与饱和失真

①截止失真



②饱和失真

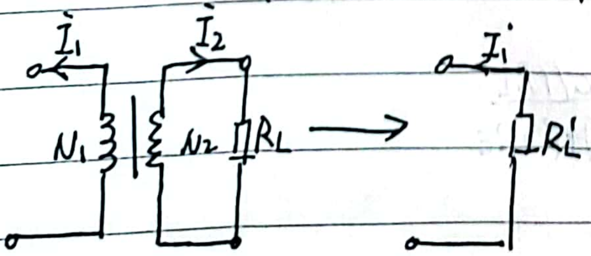


第三章：集成运算放大电路

1. 多级放大电路

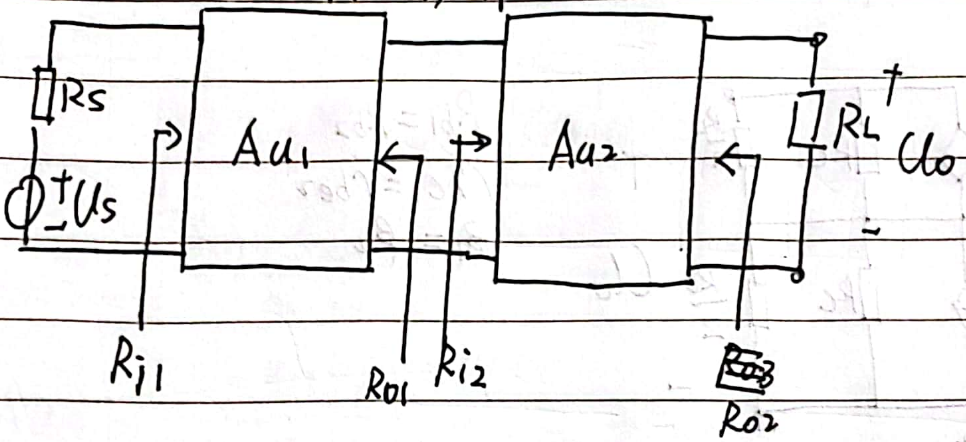
①耦合方式

- 直接耦合
  - 优点：(i) 低频特性好　(ii) 易于集成
  - 缺点：(i) 调试难　(ii) 静态工作点Q不稳定
- 阻容耦合
  - 优点：(i) 调试容易　(ii) 静态工作点Q稳定
  - 缺点：(i) 低频特性差　(ii) 不易集成
- 变压器耦合：优点：阻抗变换
- 光电耦合：优点：抗干扰好

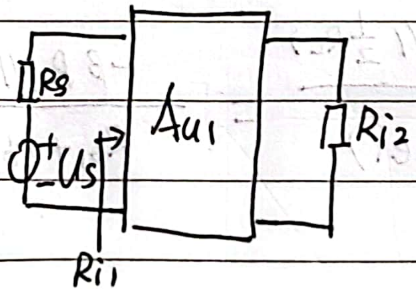


$$R_L' = \left(\frac{N_1}{N_2}\right)^2 \cdot R_L$$

2.多级放大电路的动态分析



①求Ri2 → 等效电路



②求Ri1

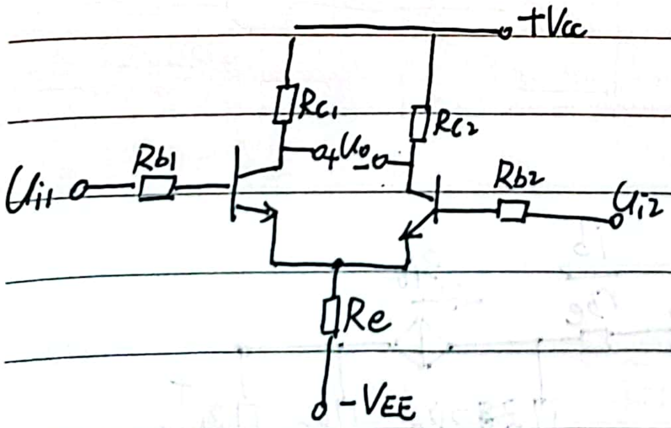
求Ro1和Ro2方法同理

放大倍数 $A_u = \frac{U_o}{U_i} = A_{u1} \cdot A_{u2}$

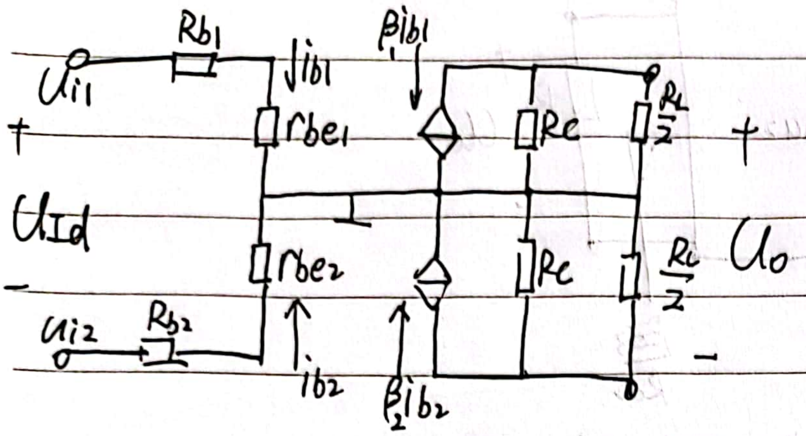
3.差分放大电路

信号 { 共模： $U_{i1} = U_{i2}$ 干扰信号
差模： $U_{i1} = -U_{i2}$ 有效信号

①长尾式差分放大电路



差模信号的交流通路 ☆☆



$R_{b1}=R_{b2}$
$r_{be1}=r_{be2}$
$\beta_1=\beta_2$

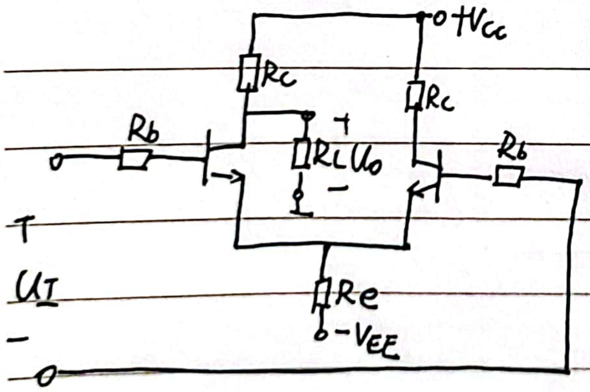
$$A_{ud}=\frac{-2\beta\cdot i_{b1}\cdot(R_C//\frac{1}{2}R_L)}{2i_{b1}\cdot(R_{b1}+r_{be1})}=\frac{-\beta R_C//\frac{1}{2}R_L}{R_{b1}+r_{be1}}$$

$R_i=2(R_{b1}+r_{be1})$

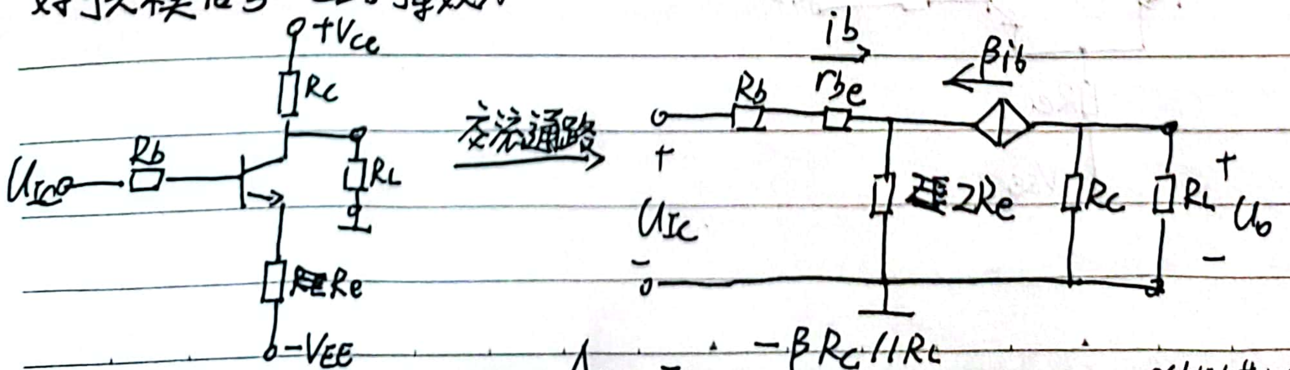
$R_o=2R_C$

②其他接法

(i) 双入单出

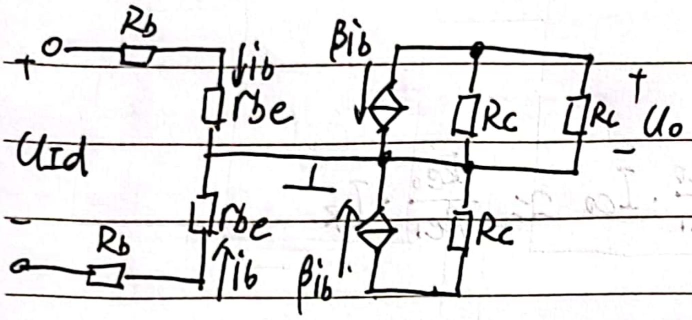


对于共模信号 电路可等效为



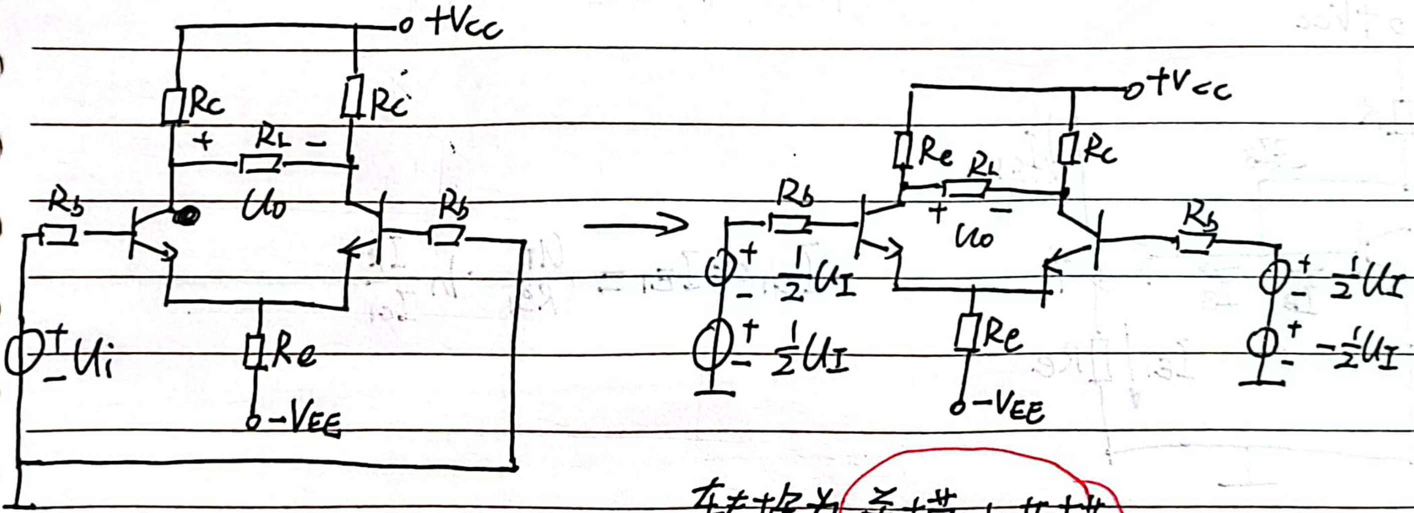
$$A_{uc}=\frac{-\beta R_C//R_L}{R_b+r_{be}+(1+\beta)\cdot 2R_e}\approx -5\%\text{(共模抑制)}$$

对于差模信号



$$A_{ud} = \frac{-\beta i_b \cdot R_c // R_L}{2 i_b \cdot (R_b + r_{be})} = \frac{-\beta \cdot R_c // R_L}{2(R_b + r_{be})}$$

(ii) 单入双出



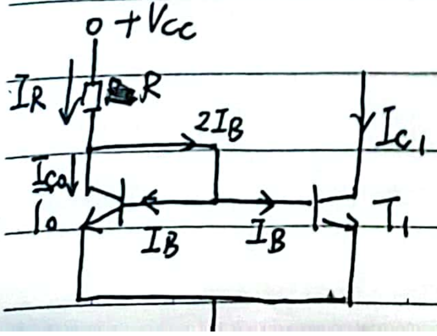
转换为差模+共模

(iii) 单入单出 ⟶ 相当于双入单出

4. 电流源电路（了解）

基本电流源

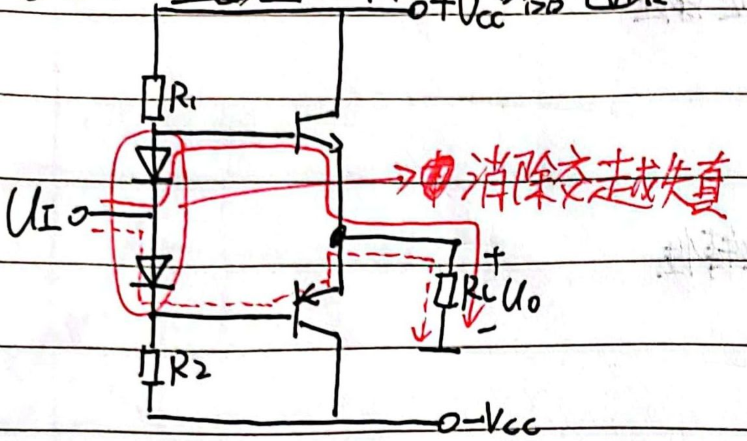
①镜像

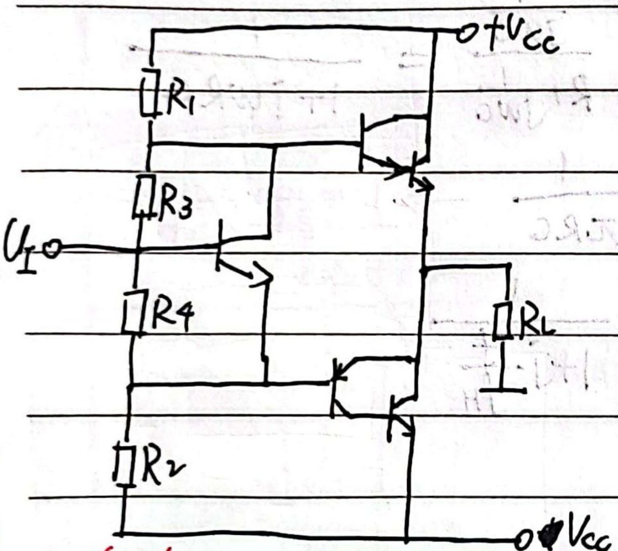


$$I_{C1} = I_{C0} = \frac{\beta + 2}{\beta} I_R \approx I_R \quad (\beta >> 2)$$

5. 互补输出级

OCL：无输出电容器电路



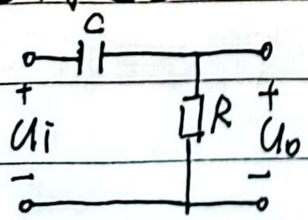


采用复合管的互补输出级

第四章小结：放大电路的频率响应

1. 基本概念（高通电路、低通电路、波特图）

① 高通电路

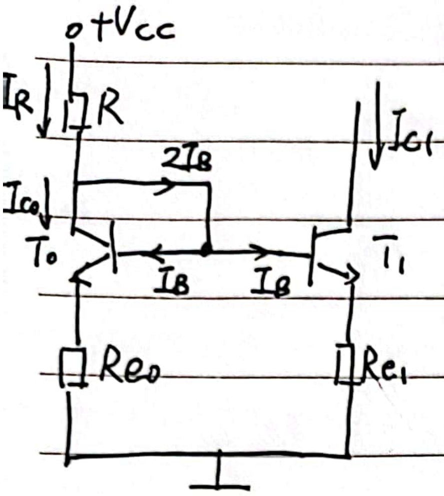


传输特性：$\dot{A}_u = \frac{R}{R+\frac{1}{j\omega C}} = \frac{1}{1+\frac{1}{j\omega RC}}$

令 $f_L = \frac{1}{2\pi RC}$ → 下限截止频率

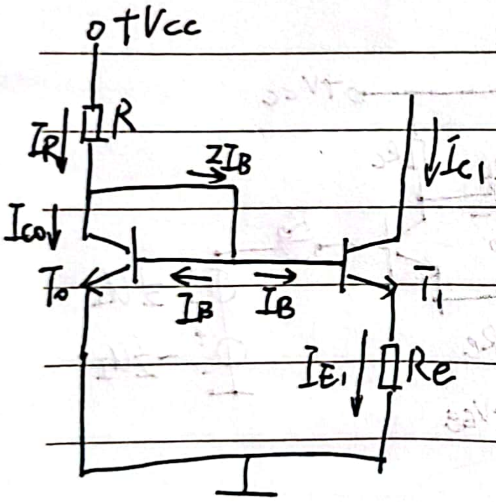
$\Rightarrow \dot{A}_u = \frac{j\frac{f}{f_L}}{1+j\frac{f}{f_L}}$

②比例电流源



$$I_{C1} \approx \frac{R_{e0}}{R_{e1}} \cdot I_{C0} \approx \frac{R_{e0}}{R_{e1}} \cdot I_R$$

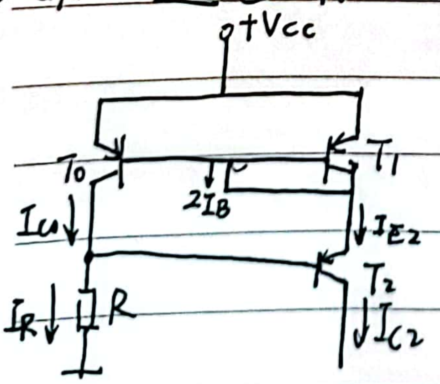
③微电流源



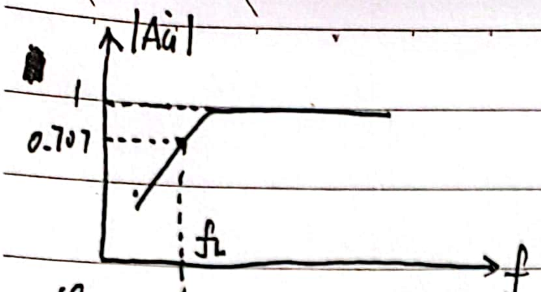
$$I_{C1} \approx I_{E1} = \frac{U_T}{R_{e1}} \cdot \ln\frac{I_R}{I_{C1}}$$

改进型电流源

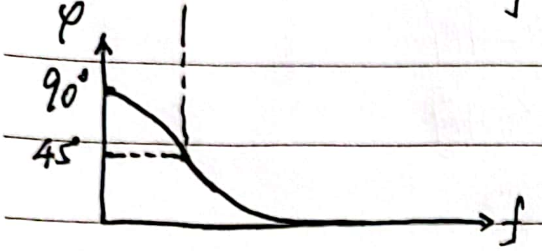
①威尔逊电流源



$$I_{C2} = I_R \cdot \left(1 - \frac{2}{\beta^2 + 2\beta + 2}\right)$$

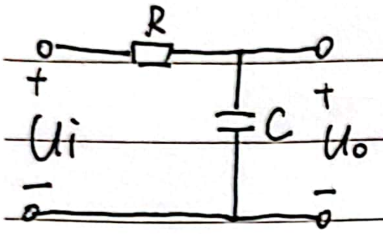


幅频特性



相频特性

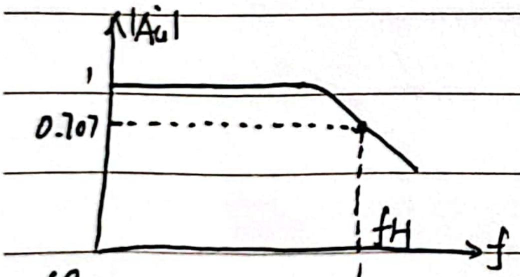
② 低通电路



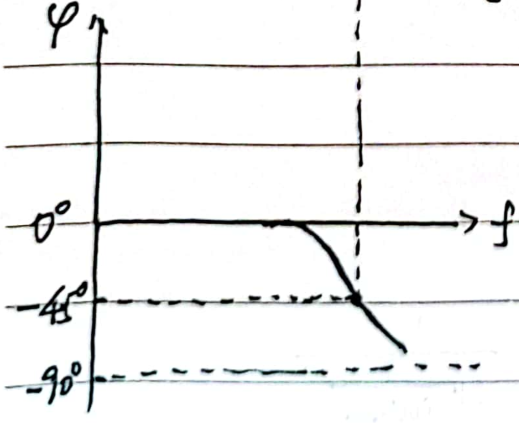
传输特性：$\dot{A}_u = \dfrac{\frac{1}{j\omega C}}{R+\frac{1}{j\omega C}} = \dfrac{1}{1+j\omega RC}$

令 $f_H = \dfrac{1}{2\pi RC}$ → 上限截止频率

$\Rightarrow \dot{A}_u = \dfrac{1}{1+j\frac{f}{f_H}}$



幅频特性

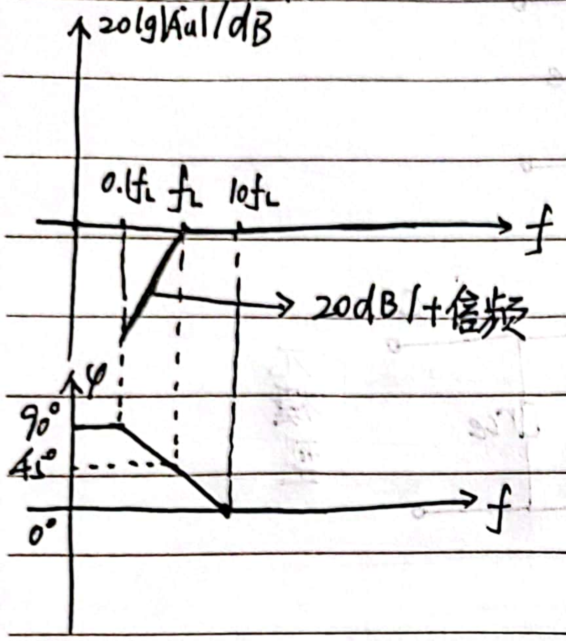


相频特性

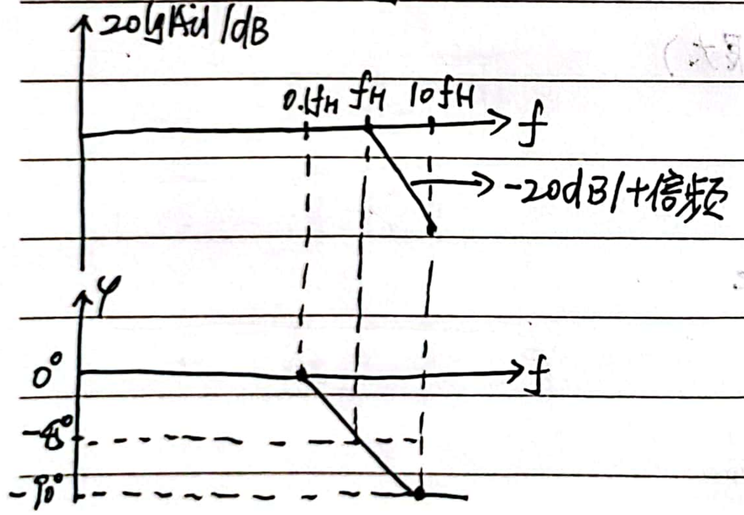
③ 波特图

变纵坐标 $|\dot{A}_u|$ 为 $20\lg|\dot{A}_u|$

1. 高通电路的波特图



低通电路的波特图

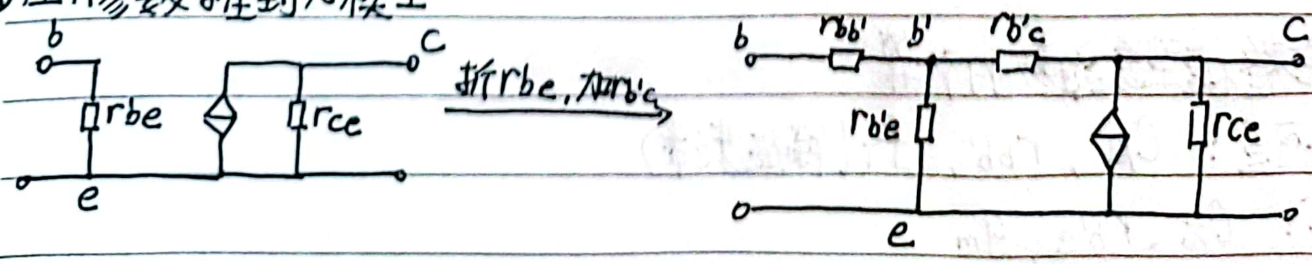


0dB → 不放大　　>0dB → 放大　　<0dB → 减小

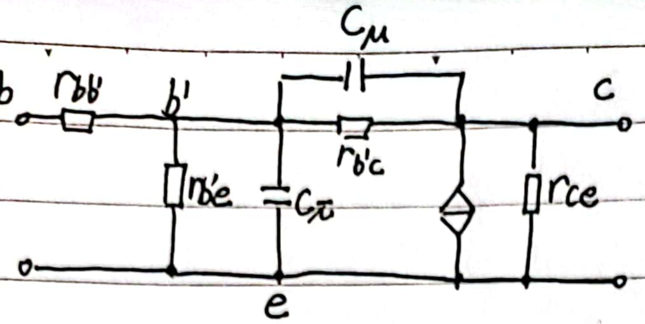
斜率:（n级放大电路 × 20dB/十倍频）

2. 混合π模型（了解，不知道会不会考这么难）

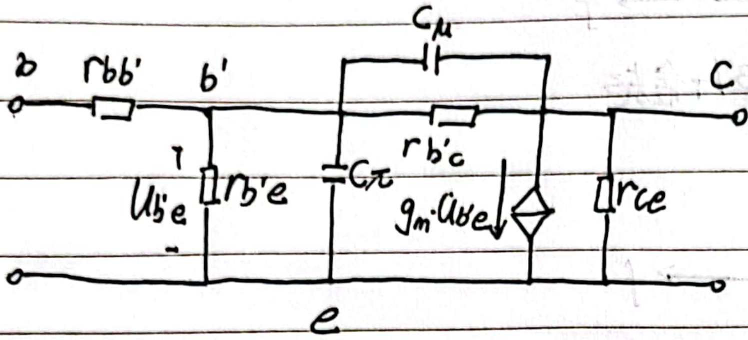
①由H参数推到π模型



加极间电容→



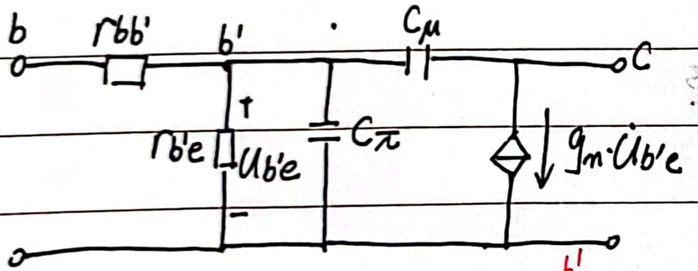
修改受控源→



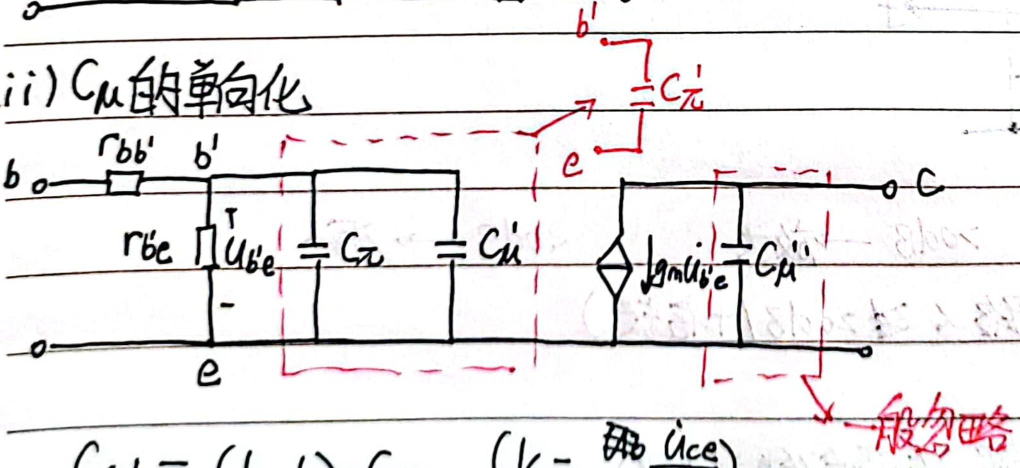
π模型

② 不完整模型

i) 由π模型去 $r_{b'c}$、r_{ce} 得（$r_{b'c}$、r_{ce}很大）



(ii) C_μ的单向化



$C_\mu' = (1-k) \cdot C_\mu \quad (k = \frac{U_{ce}}{U_{be}})$

③ 不完整模型参数的计算

手册可查：C_μ，$r_{bb'}$，f_T（特征频率）

待求：C_π、$r_{b'e}$，g_m

(i) $r_{b'e} = (1+\beta_0)\cdot \frac{U_T}{I_{EQ}}$ （用静态工作点Q）

(ii) $\frac{\dot{I}_c}{\dot{I}_B} = \frac{g_m \cdot \dot{U}_{b'e}}{\dot{U}_{b'e}/r_{b'e}} = g_m \cdot r_{b'e} = \beta_0$

$\Rightarrow g_m = \frac{\beta_0}{r_{b'e}}$

(iii) 当 $f = f_T$ 时（特征频率也是截止频率）

$k = \frac{\dot{U}_{ce}}{\dot{U}_{be}} = 0 \Rightarrow C_{\mu}' = C_{\mu}$

$C_{\pi}' = C_{\pi} + C_{\mu}' = \frac{1}{2\pi(r_{b'e}+r_{bb'})\cdot f_T}$

$\Rightarrow C_{\pi} = \frac{1}{2\pi(r_{b'e}+r_{bb'})f_T} - C_{\mu}' = \frac{1}{2\pi(r_{b'e}+r_{bb'})f_T} - C_{\mu}$

（注：这仅是在 $f=f_T$ 情况下，其余情况 $C_{\mu}' = C_{\mu}(1-k)$ 会变化）

3. 利用混合π模型求解电路波特图的一般步骤

① 求解静态工作点Q，求用Q点求解不完整模型中的其他参数

② 求出中频段情况下的 $\dot{A}_{usm}$

③ 低频段（高通电路），求~~阻容耦合~~用于消除输出直流信号的电容的等效电阻

得到 $f_L = \frac{1}{2\pi R_{等} C}$

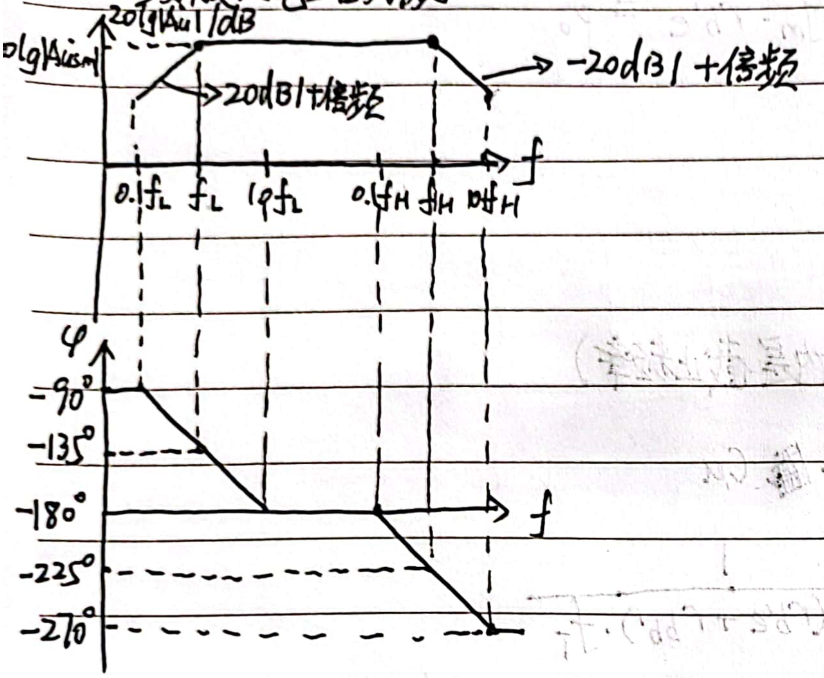
④ 高频段（低通电路），求三极管极间电容 C_{π}' 的等效电阻，得到

$f_H = \frac{1}{2\pi R_{等} C_{\pi}'}$

⑤画波特图

以 $A_{usm}<0$ 为例（大于0则幅角范围为 ~~$-90^\circ \sim -270^\circ$~~ $-90^\circ \sim 90^\circ$）

以一级放大电路为例



4、增益带宽积

放大倍数与通频带宽度乘积为一个定值

5.多级放大电路的频率响应

$$f_L = 1.1\cdot\sqrt{\sum_{i=1}^{k} f_{Li}^2}$$

$$\frac{1}{f_H} = 1.1\sqrt{\sum_{i=1}^{k}\frac{1}{f_{Hi}^2}}$$

RC最小的一级放大电路对 f_L 影响最大

RC最大的一级放大电路对 f_H 影响最大

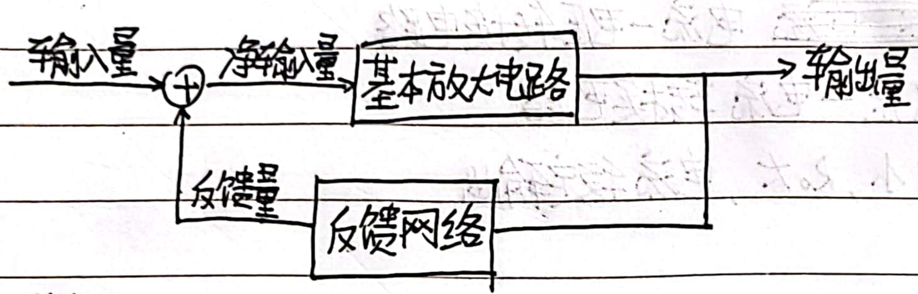
第五章：放大电路中的反馈☆

1、基本概念

①反馈：部分 or 全部输出量对输入量的影响

②类型 {正反馈 / 负反馈} {串联 / 并联} {直流 / 交流} {电压 / 电流}

③反馈放大电路的方框图



④反馈的判断

(i) 存在与否 {看结构 / 看反馈量能否引起响应（原信号源置0，输出量作为信号源）}

(ii) 正负判断 ⟶ 瞬时极性法

☆ 反馈信号、输入信号：

- 相异端子 极性 {相同 ⟶ 负；相反 ⟶ 正}
- 相同端子 极性 {相同 ⟶ 正；相反 ⟶ 负}

(iii) 交流、直流判断

看直流通路、交流通路中反馈网络是否存在

（注：对于直接耦合放大~~网络~~电路，只要存在直流反馈，就存在交流反馈）

~~(iii)~~ (iv) 电压 or 电流判断

输出电压 U_o 置0 ⟶ 反馈消失 ⟶ 电压

⟶ 反馈依然存在 ⟶ 电流

(v) 串并联判断

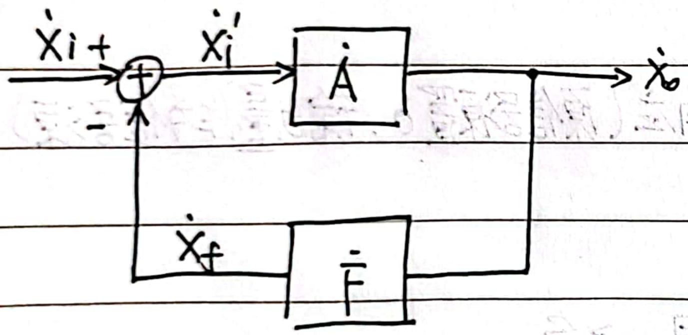
☆ 相异端子 → 串联
相同端子 → ~~电流~~并联

由上述类型组合得到负反馈的四种组态

- 电压串联 → R_i 大，R_o 小，电压稳定输出
- 电压并联 → ~~电压一电流~~ 电流一电压转换电路
- 电流串联 → 电压一电流 转换电路
- 电流并联 → R_i 小，R_o 大，电流稳定输出

2. 方块图

①



$$\begin{cases} \dot{X}_o = \dot{A}\cdot\dot{X}_i' \\ \dot{X}_f = \dot{F}\cdot\dot{X}_o \\ \dot{X}_i' = \dot{X}_i - \dot{X}_f \end{cases}$$

(i) 闭环放大倍数

$$\dot{A}_f = \frac{\dot{X}_o}{\dot{X}_i} = \frac{\dot{A}\dot{X}_i'}{\dot{X}_i' + \dot{A}\cdot\dot{F}\cdot\dot{X}_i'} = \frac{\dot{A}}{1+\dot{A}\dot{F}}$$

(ii) 环路放大系数：$\dot{A}\dot{F}$

(iii) 反馈深度：$|1+\dot{A}\dot{F}|$

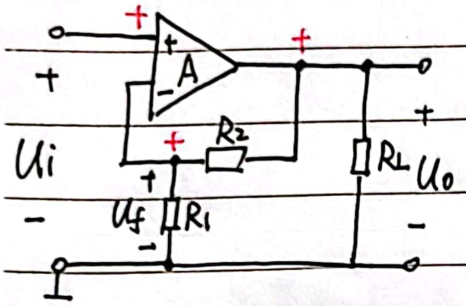
② 深度负反馈

当 $\dot{A}$ 很大时 $\dot{A}_f = \dfrac{\dot{A}}{1+\dot{A}\dot{F}} = \dfrac{1}{\dot{F}}$

深度负反馈的实质：忽略了 $\dot{X}_i'$（净输入量）→ “虚短”

③ 四种组态的反馈放大电路在深度负反馈下的分析

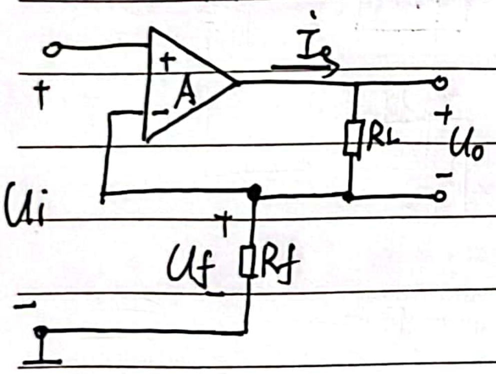
(i) 电压串联



$$\dot{F}_{uu} = \frac{\dot{U}_f}{\dot{U}_o} = \frac{\frac{R_1}{R_1+R_2}\dot{U}_o}{\dot{U}_o} = \frac{R_1}{R_1+R_2}$$

$$\dot{A}_{uuf} = \frac{1}{\dot{F}_{uu}} = 1+\frac{R_2}{R_1}$$

(ii) 电流串联

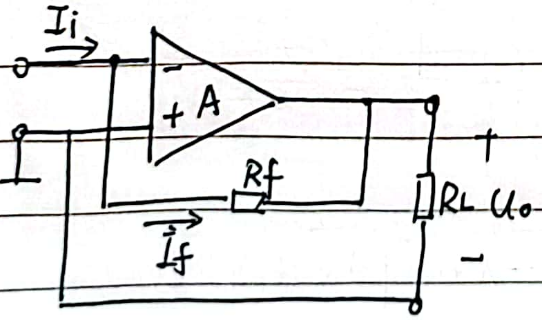


$$\dot{F}_{ui} = \frac{\dot{U}_f}{\dot{I}_o} = \frac{\dot{I}_o \cdot R_f}{\dot{I}_o} = R_f$$

$$\dot{A}_{iuf} = \frac{1}{\dot{F}_{ui}} = \frac{1}{R_f} \left(= \frac{\dot{I}_o}{\dot{U}_i}\right)$$

$$\dot{A}_{uuf} = \frac{\dot{U}_o}{\dot{U}_i} = \frac{\dot{I}_o \cdot R_L}{\dot{U}_i} = \frac{R_L}{R_f}$$

(iii) 电压并联

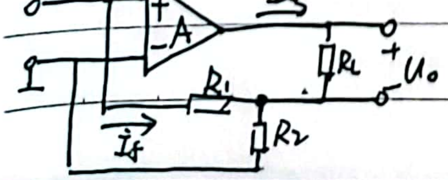


$$\dot{F}_{iu} = \frac{\dot{I}_f}{\dot{U}_o} = \frac{\frac{0-\dot{U}_o}{R_f}}{\dot{U}_o} = -\frac{1}{R_f}$$

$$\dot{A}_{uif} = \frac{\dot{U}_o}{\dot{I}_i} = \frac{1}{\dot{F}_{iu}} = -R_f$$

$$\dot{A}_{usf} = \frac{\dot{U}_o}{\dot{U}_s} = \frac{\dot{U}_o}{\dot{I}_i \cdot R_s} = -\frac{R_f}{R_s}$$

(iv) 电流并联



$$\dot{F}_{ii} = \frac{\dot{I}_f}{\dot{I}_o} = \frac{-\frac{R_2}{R_1+R_2}\dot{I}_o}{\dot{I}_o} = -\frac{R_2}{R_1+R_2}$$

$$\dot{A}_{iif} = \frac{\dot{I}_o}{\dot{I}_i} = \frac{1}{\dot{F}_{ii}} = -\left(1+\frac{R_1}{R_2}\right)$$

$$\dot{A}_{usf} = \frac{\dot{U}_o}{\dot{U}_s} = \frac{R_L \cdot \dot{I}_o}{R_s \cdot \dot{I}_i} = -\frac{R_L}{R_s}\left(1+\frac{R_1}{R_2}\right)$$

☆3. 负反馈对放大电路性能的影响

①稳定放大倍数，但放大倍数下降了(1+AF)倍

② ~~串联 { Ri 放大(1+AF)倍~~
~~Ro 缩~~

输入电阻 { 串联：放大(1+AF)倍
并联：减小(1+AF)倍

③ 输出电阻 { 电流：放大(1+AF)倍
电压：减小(1+AF)倍

④ 展宽频带(1+AF)倍

4. 负反馈放大电路的稳定性

①自激振荡产生的原因

$\dot{X}_i' = \dot{X}_i - \dot{X}_f = \dot{X}_i - \dot{A}\dot{F}\dot{X}_i$

在中频段 $|\dot{X}_i'| = |\dot{X}_i| - |\dot{A}\dot{F}\dot{X}_i|$

若在高频段某一频率下 $\varphi_A + \varphi_F = 180°$

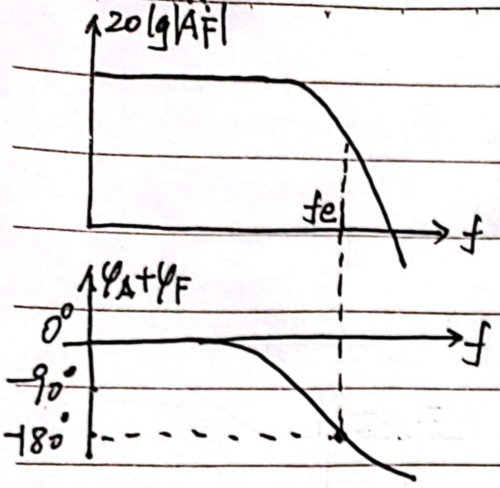
$|\dot{X}_i'| = |\dot{X}_i| + |\dot{A}\dot{F}\dot{X}_i|$ ⟶ 正反馈

②自激振荡的平衡条件

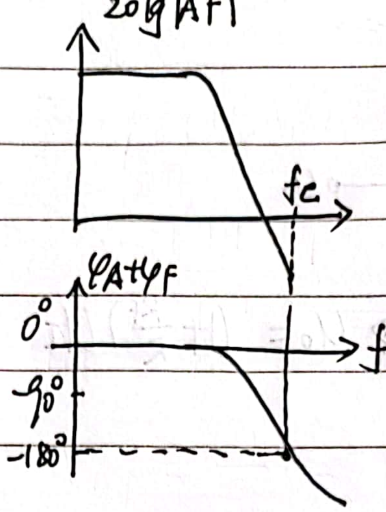
$f: \begin{cases} \varphi_A + \varphi_F = 180° \\ |\dot{A}\dot{F}| = 1 \end{cases}$

起振：$|\dot{A}\dot{F}| \geq 1$

③能否起振的判断



可以起振



不能起振

④ 防止自激振荡的措施

加低通电路电容，使到达 -180° 之间 ~~放大倍数~~ $20\lg|\dot{A}\dot{F}|$ 衰减为0

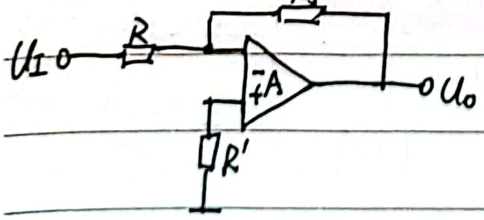
第六章：信号的运算和处理

1. 核心：{ 虚短：$u_P = u_N$ （深度负反馈条件下）
虚断：$i_I = 0$
$i_N = i_P = 0$

2. 运算电路

(1) 反相比例

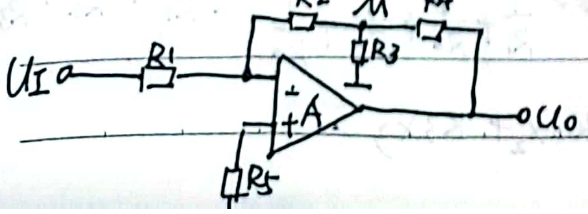
① 基本反相比例运算电路 ($y = -kx$)



$$\frac{u_I - 0}{R} = \frac{0 - u_O}{R_f}$$

$$\Rightarrow u_O = -\frac{R_f}{R} u_I$$

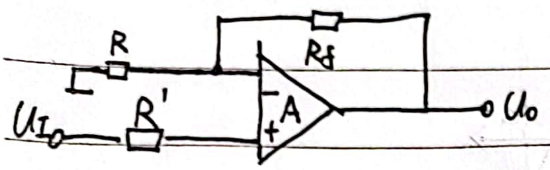
② T型网络反相比例运算电路



$$\begin{cases} \frac{u_I - 0}{R_1} = \frac{0 - u_M}{R_2} \\ \frac{0 - u_M}{R_2} = \frac{u_M}{R_3} + \frac{u_M - u_O}{R_4} \end{cases}$$

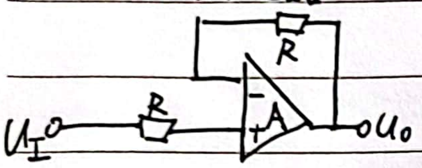
$$\Rightarrow u_O = -\frac{R_2}{R_1} \cdot \left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right) \cdot R_4 \cdot u_I$$

(2) 同相比例　$y=kx$



$$\frac{U_I}{U_o}=\frac{R}{R+R_f}\Rightarrow U_o=\left(1+\frac{R_f}{R}\right)U_I$$

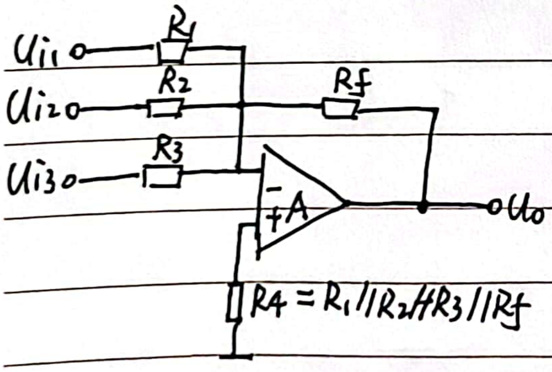
(3) 电压跟随器



3、加、减、积分、微分、指数、对数

① 加、减

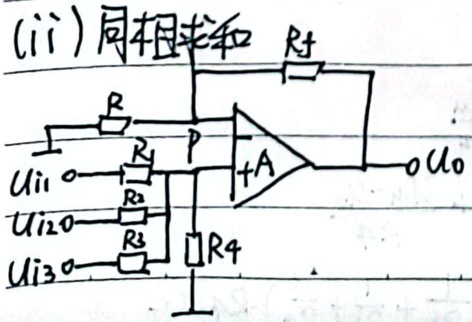
(i) 反相求和



$$U_o=-\left(\frac{R_f}{R_1}U_{I1}+\frac{R_f}{R_2}U_{I2}+\frac{R_f}{R_3}U_{I3}\right)$$

$$y=-(k_1x_1+k_2x_2+k_3x_3)$$

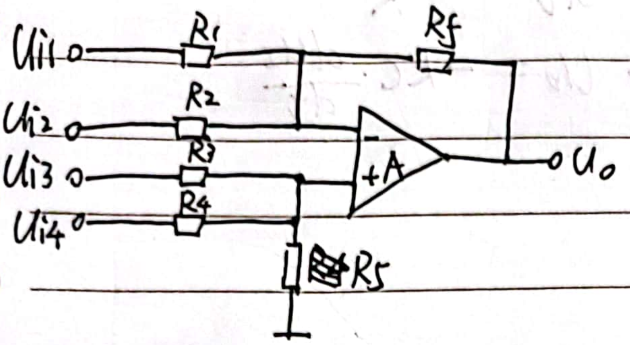
(ii) 同相求和



$$U_o=\left(1+\frac{R_f}{R}\right)\frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}}\cdot\left(\frac{U_{i1}}{R_1}+\frac{U_{i2}}{R_2}+\frac{U_{i3}}{R_3}\right)$$

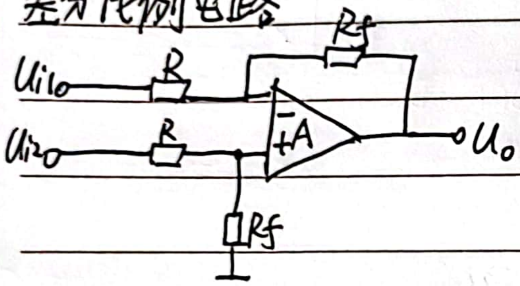
$$y=k_1x_1+k_2x_2+k_3x_3$$

(iii) 加、减

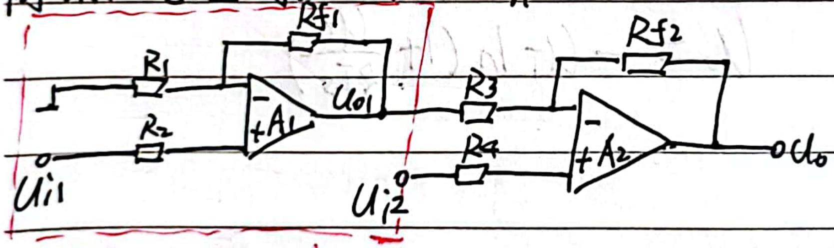


同相加、反相减

差分比例电路



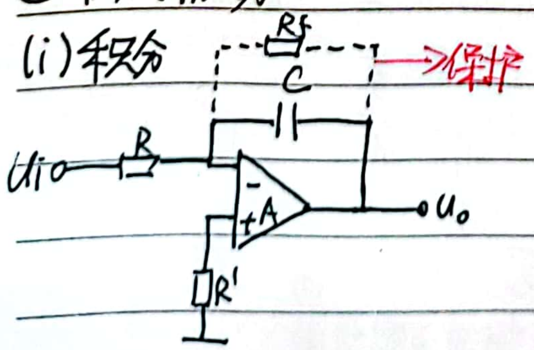
高输入电阻的差分比例运算电路



同相比例→高输入电阻

② 积分、微分

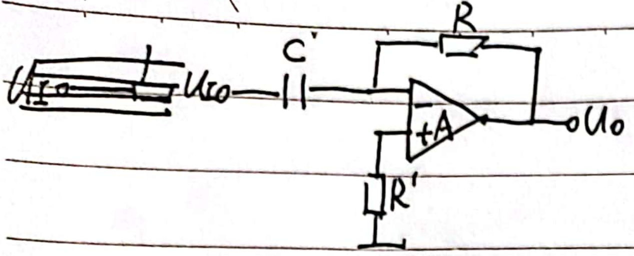
(i) 积分



$$\frac{U_i - 0}{R} = -C \cdot \frac{du_o}{dt}$$

$$\Rightarrow U_o = -\frac{1}{RC}\int u_i dt$$

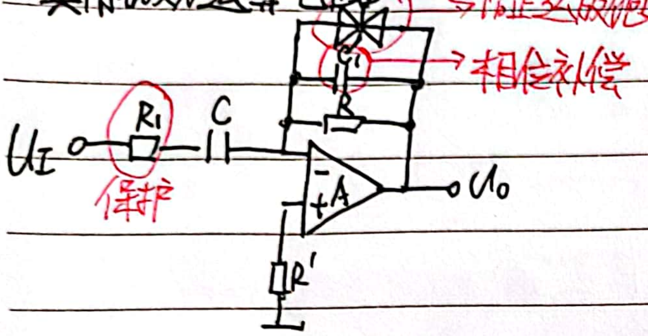
(ii) 微分



$$C\frac{du_I}{dt} = \frac{0-u_O}{R}$$

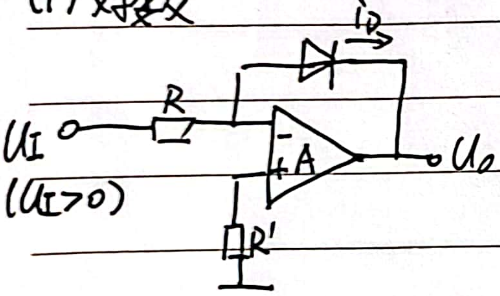
$$\Rightarrow u_O = -RC\cdot\frac{du_I}{dt}$$

实用微分运算电路



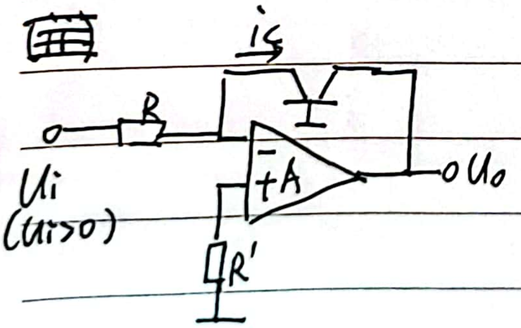
③ 对数、指数

(i) 对数



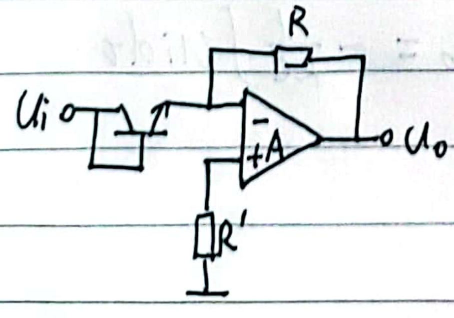
$$\frac{u_I}{R} = I_S\cdot\left(e^{-\frac{u_O}{U_T}}-1\right)$$

$$u_O = -U_T\ln\left(1+\frac{u_I}{RI_S}\right)$$

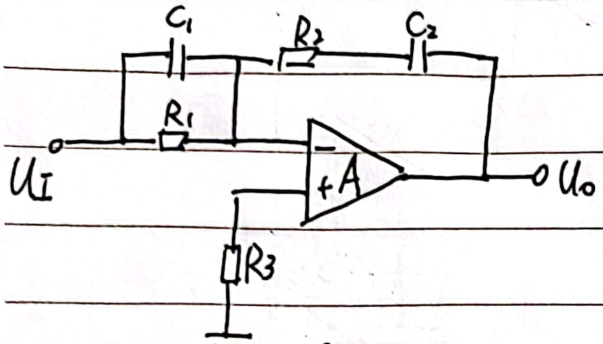


用三极管代替二极管，让动态范围加大

(ii) 指数



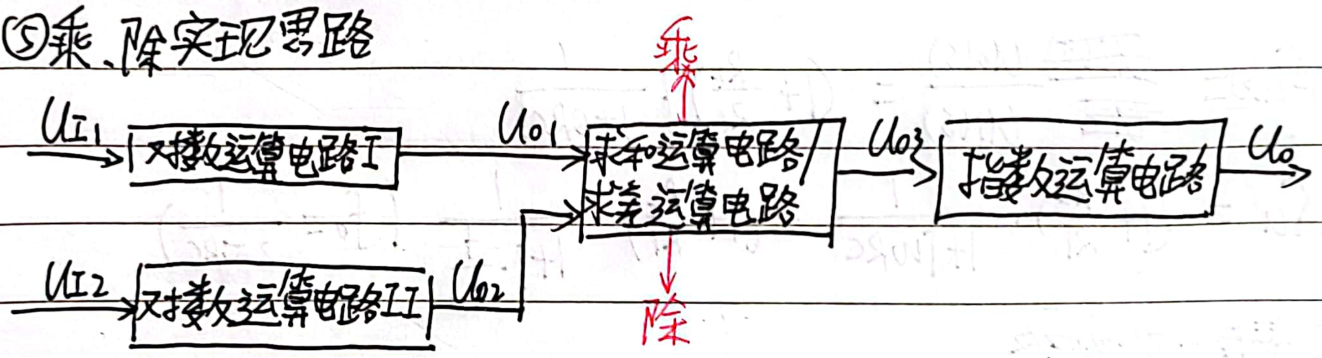
④PID控制器



$$u_o = -\left(\frac{R_2}{R_1}+\frac{C_1}{C_2}\right)u_I - R_2C_1\cdot\frac{du_I}{dt} - \frac{1}{C_2}\int\frac{u_I}{R_1}dt$$

P　　D　　I

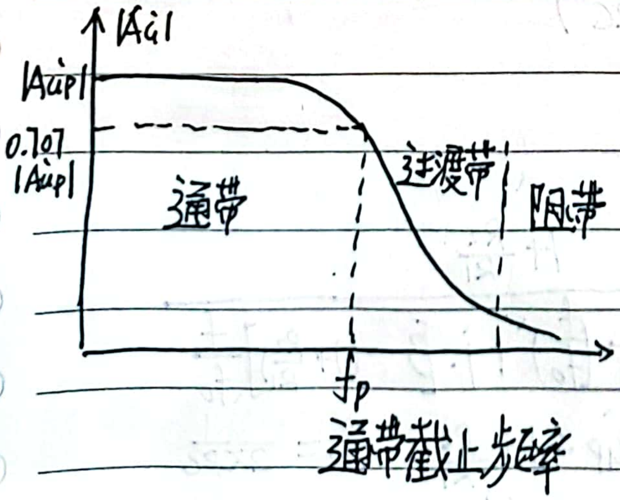
⑤乘、除实现思路



4.有源滤波电路(掌握一阶即可)

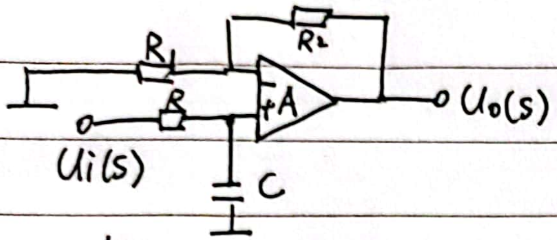
(1)概念：对于信号的频率具有选择性的电路

(2)分类：低通(LPF)、高通(HPF)、带通(BPF)、带阻(BEF)
全通(APF)



(3) 低通滤波器

① 同相输入低通滤波器

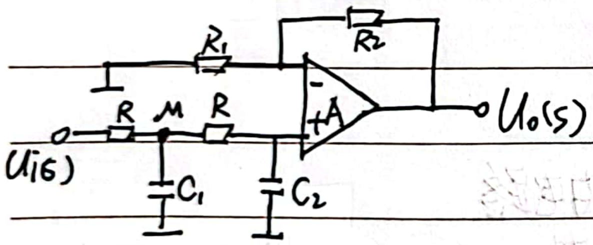


$$\frac{\frac{\frac{1}{sC}}{\frac{1}{sC}+R}U_i(s)}{U_o(s)} = \frac{R_1}{R_1+R_2}$$

$$\dot{A}_u(s) = \frac{U_o(s)}{U_i(s)} = \left(1+\frac{R_2}{R_1}\right)\cdot\frac{1}{1+sRC}$$

$$\dot{A}_u = \left(1+\frac{R_2}{R_1}\right)\cdot\frac{1}{1+j\omega RC} = \left(1+\frac{R_2}{R_1}\right)\cdot\frac{1}{1+j\cdot\frac{f}{f_0}} \quad \left(f_0=\frac{1}{2\pi RC}\right)$$

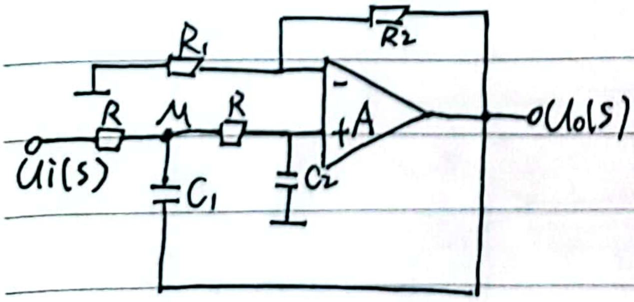
② 简单二阶电路



$C_1=C_2=C$

$$\dot{A}_u = \frac{1+\frac{R_2}{R_1}}{1-\left(\frac{f}{f_0}\right)^2+j\cdot 3\frac{f}{f_0}} \quad \left(f_0=\frac{1}{2\pi RC}\right)$$

③ 压控电压源二阶低通滤波电路



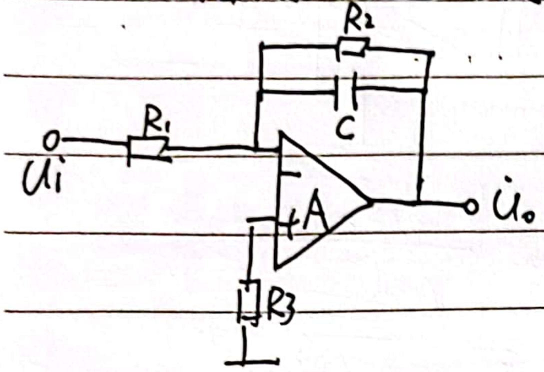
$$\dot{A}_u = \frac{1+\frac{R_2}{R_1}}{1-\left(\frac{f}{f_0}\right)^2+j\cdot\left[3-\left(1+\frac{R_2}{R_1}\right)\right]\frac{f}{f_0}}$$

令 $\dot{A}_{up}=1+\frac{R_2}{R_1}$ $\quad f_0=\frac{1}{2\pi RC}$

$$\dot{A}_u = \frac{\dot{A}_{up}}{1-\left(\frac{f}{f_0}\right)^2+j\cdot\left[3-\dot{A}_{up}\right]\frac{f}{f_0}}$$

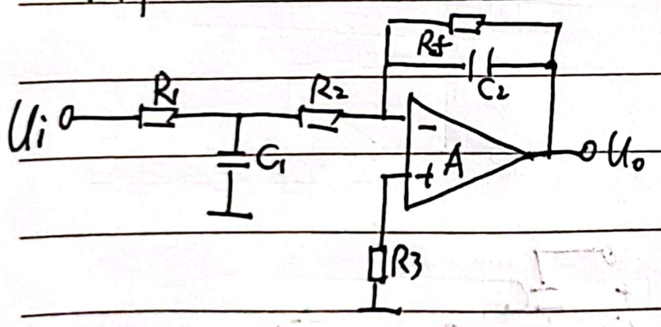
只有 $\dot{A}_{up}=1+\frac{R_2}{R_1}$ 小于3才不产生自激振荡☆

④ 一阶反相输入低通滤波器

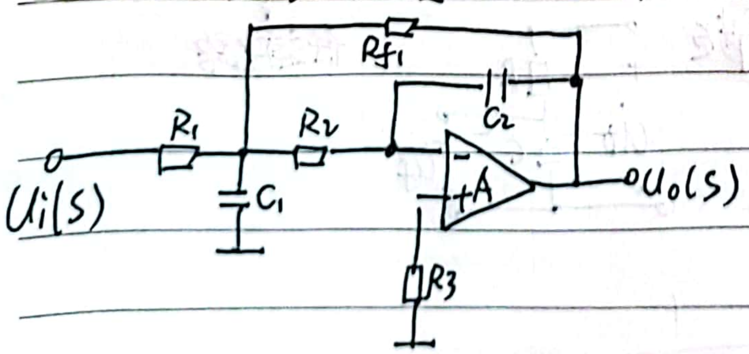


$$\dot{A}_u=\frac{\dot{A}_{up}}{1+j\frac{f}{f_0}}\quad\left(\dot{A}_{up}=-\frac{R_2}{R_1},\ f_0=\frac{1}{2\pi R_2C}\right)$$

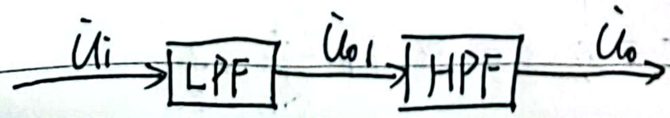
⑤ 简单二阶低通滤波电路(同相)



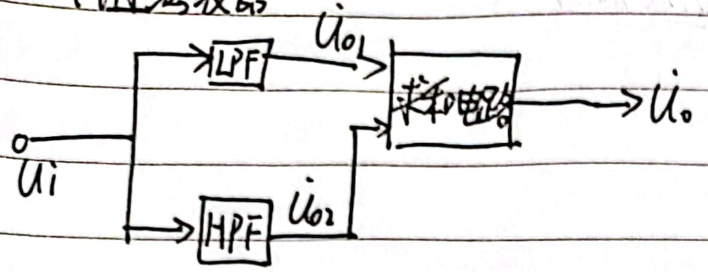
⑥ 无限增益多路反馈二阶低通滤波电路



(4) 带通滤波器



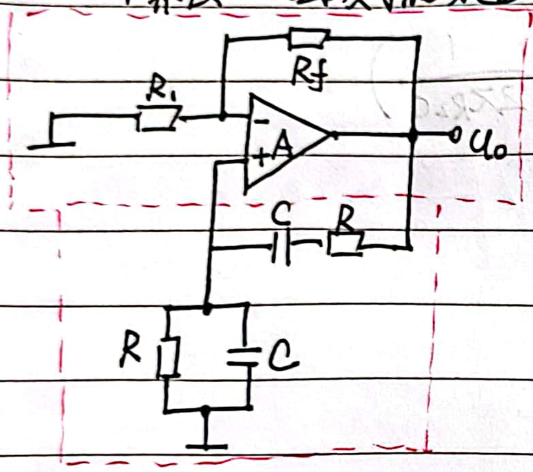
(5) 带阻滤波器



第七章：波形的发生和信号的转换

1、正弦波振荡电路 ☆☆

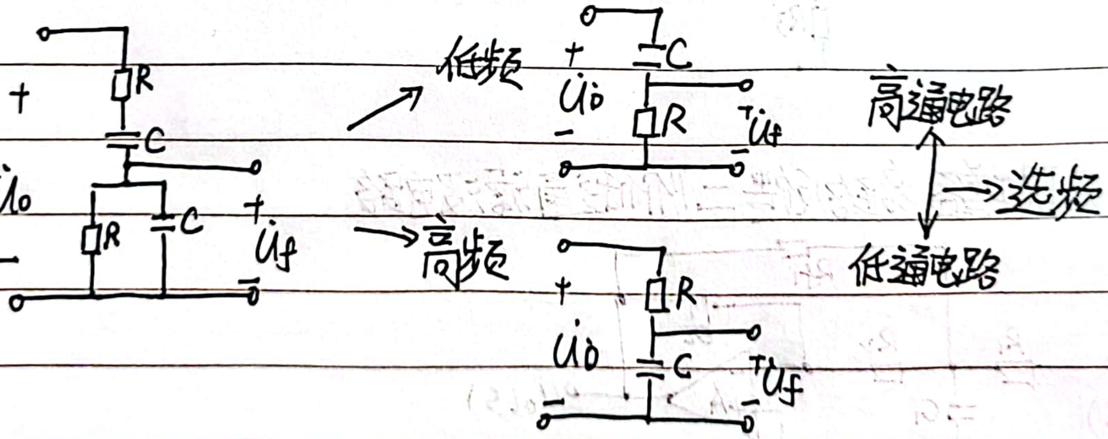
① RC桥式正弦波振荡电路



[A] $1+\frac{R_f}{R_1}$

[F]

F网络



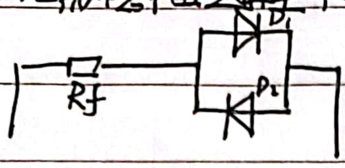
$$\frac{\dot U_f}{\dot U_o} = \frac{R//\frac{1}{j\omega C}}{R+\frac{1}{j\omega C}+R//\frac{1}{j\omega C}} = \frac{1}{3+(\omega RC-\frac{1}{\omega RC})j}$$

☆☆

$\Rightarrow \omega_0 = \frac{1}{RC}$ （选频） 此时 $\frac{\dot U_f}{\dot U_o} = \frac{1}{3}$ ⟶ $1+\frac{R_f}{R_1} > 3$

需要起振

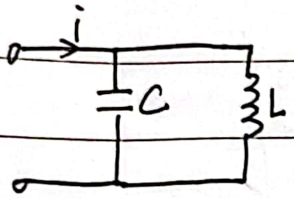
选频放大后需稳幅选择，则加入二极管作为非线性环节



T↑ D1、D2电阻↓

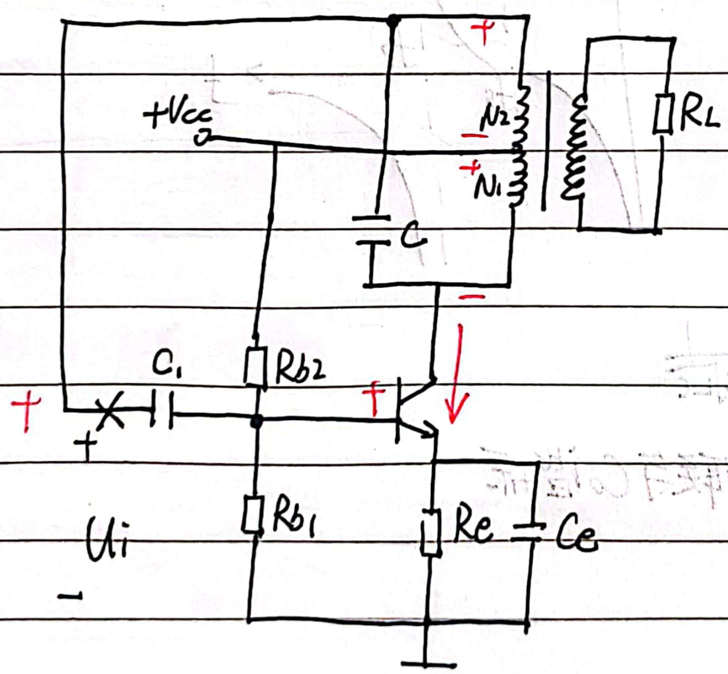
②LC正弦波振荡电路

LC并联网络



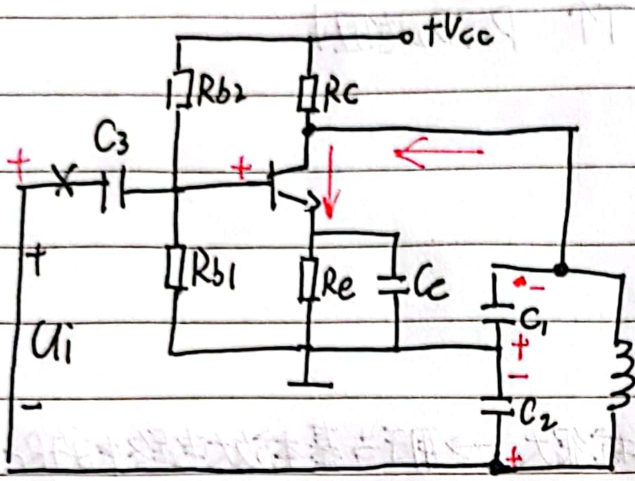
谐振时阻抗很大 → 用于当基本放大电路中的R_c

电感反馈式振荡电路



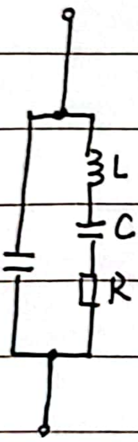
但电感反馈式振荡电路易产生高次谐波

电容叁反馈式振荡电路

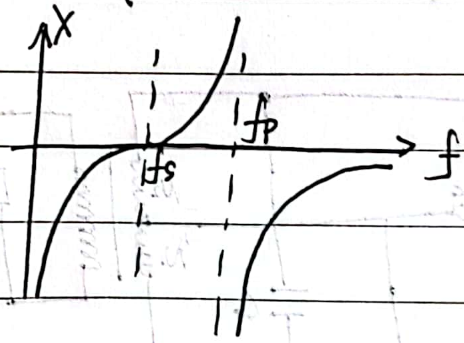


2、石英晶体谐振器(了解)

等效电路：



阻抗曲线

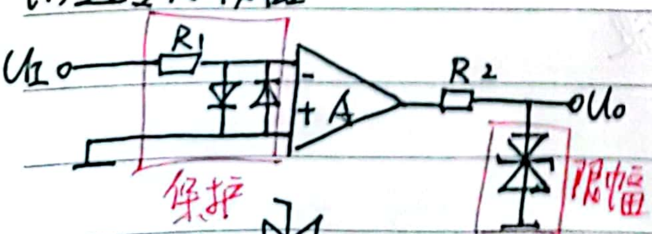


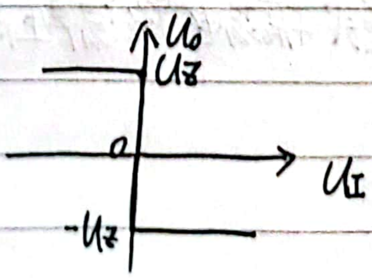
f_s → 串联谐振 $f_s=\frac{1}{2\pi\sqrt{LC}}$

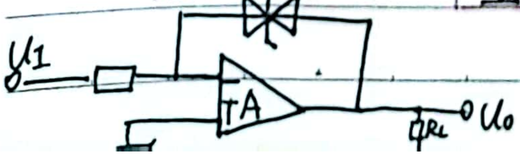
f_p → 并联谐振 RCL串联与C_0谐振

3.电压比较器

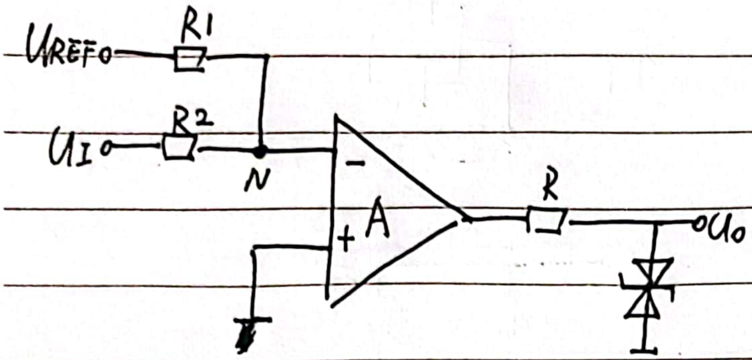
(1)过零比较器







(2) 一般单限比较器

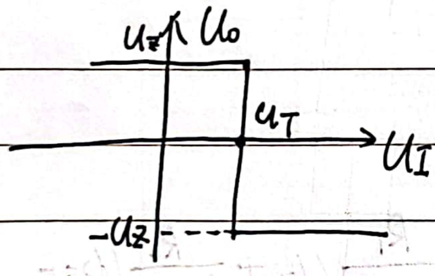


$$U_N = \frac{R_2}{R_1+R_2} U_{REF} + \frac{R_1}{R_1+R_2} U_I$$

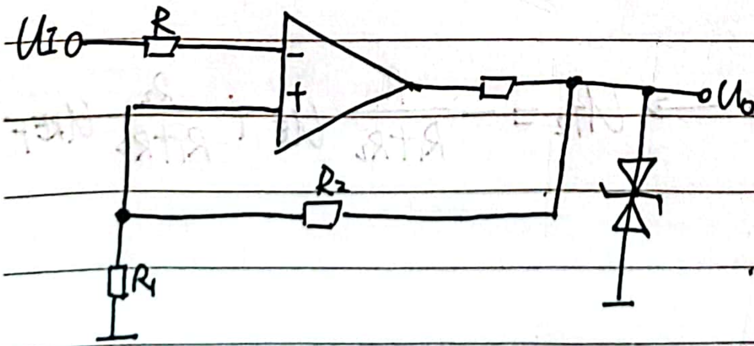
令 $U_N = U_P = 0 \Rightarrow U_T = -\frac{R_2}{R_1} U_{REF}$

当 $U_I < U_T$ 时　$U_N < U_P \rightarrow$ 正

当 $U_I > U_T$ 时　$U_N > U_P \rightarrow$ 负



(3) 滞回比较器 ☆☆☆



当 $U_o = +U_Z$ 时

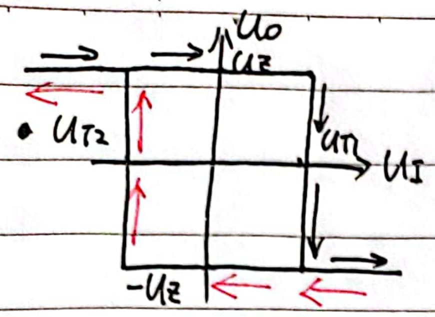
$U_P = U_Z \cdot \frac{R_1}{R_1+R_2}$

$\Rightarrow U_{T1} = U_Z \cdot \frac{R_1}{R_1+R_2}$

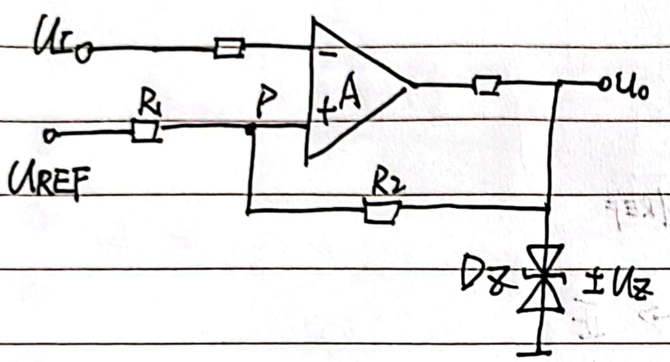
当 $U_o = -U_Z$ 时

$U_P = -U_Z \cdot \frac{R_1}{R_1+R_2}$

$\Rightarrow U_{T2} = -U_Z \cdot \frac{R_1}{R_1+R_2}$



(4) 加入了参考电压的滞回比较器



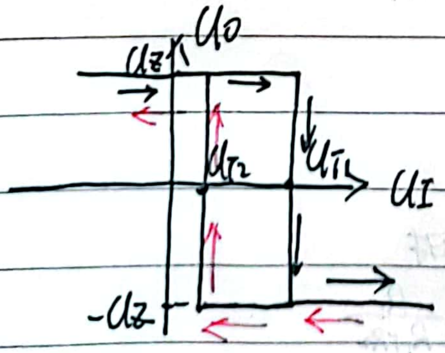
$$u_P=\frac{R_1}{R_1+R_2}u_O+\frac{R_2}{R_1+R_2}U_{REF}$$

当 $u_O=+U_Z$ 时

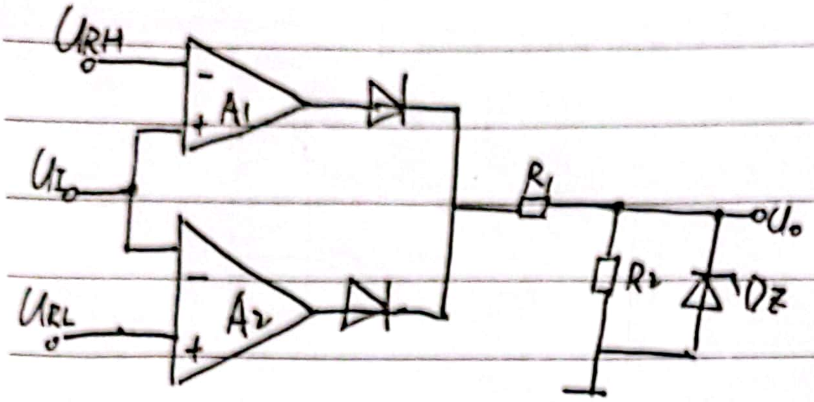
$$u_P=\frac{R_1}{R_1+R_2}U_Z+\frac{R_2}{R_1+R_2}U_{REF}\longrightarrow U_{T1}=\frac{R_1}{R_1+R_2}U_Z+\frac{R_2}{R_1+R_2}U_{REF}$$

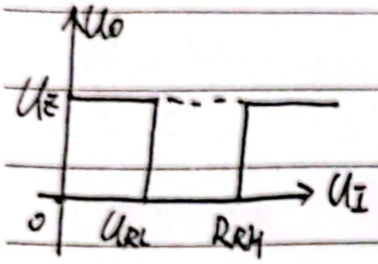
当 $u_O=-U_Z$ 时

$$u_P=-\frac{R_1}{R_1+R_2}U_Z+\frac{R_2}{R_1+R_2}U_{REF}\longrightarrow U_{T2}=-\frac{R_1}{R_1+R_2}U_Z+\frac{R_2}{R_1+R_2}U_{REF}$$



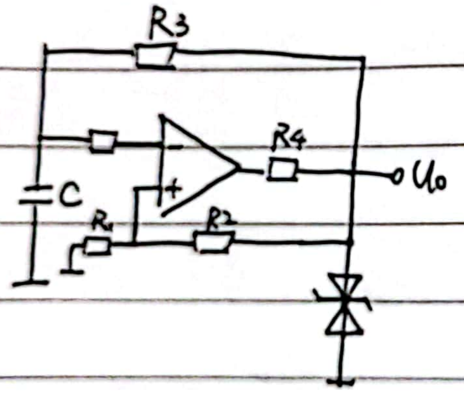
(5) 双限电压比较器





4. 非正弦波发生电路

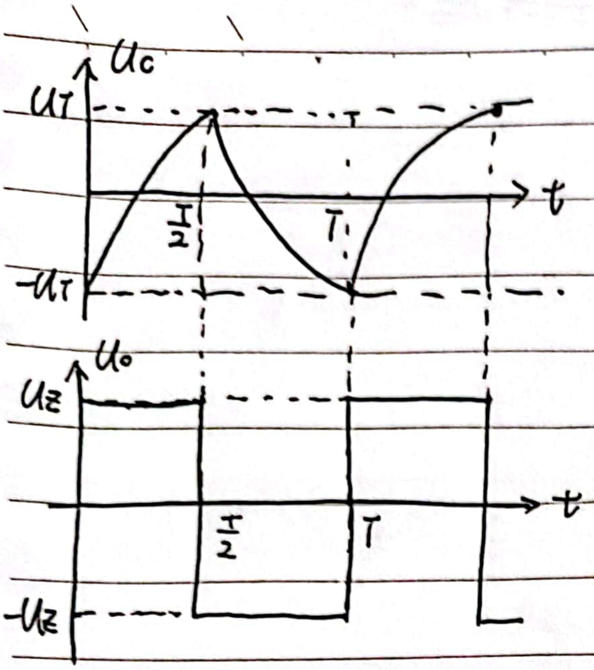
① 方波发生电路（原理：滞回比较器）☆☆☆



$$U_T = U_Z \cdot \frac{R_1}{R_1+R_2}$$

当 $u_o = U_Z$ 时，u_o 通过 R_3 给C充电，使 u_N 上升，当 u_N 大于 U_T 时，使比较器输出翻转，$u_o = -U_Z$，使 $u_P = -U_T$，u_o 通过 R_3 给C放电，使 u_N 下降，u_N 小于 $-U_T$ 时，比较器输出再次翻转，又 $u_o = U_Z$，以此循环。

↑ 原理阐述



用三要素法 写出 $0 \le t \le \frac{T}{2}$ 时 u_C 的式子

$$u_C(t) = u_C(\infty) + [u_C(0+) - u_C(\infty)]e^{-\frac{t}{\tau}}$$

$$= U_Z + (-U_T - U_Z)e^{-\frac{t}{R_3C}}$$

当 $t = \frac{T}{2}$ 时 $u_C(t) = U_T$

$$\Rightarrow U_T = U_Z + (-U_T - U_Z)\cdot e^{-\frac{T/2}{R_3C}}$$

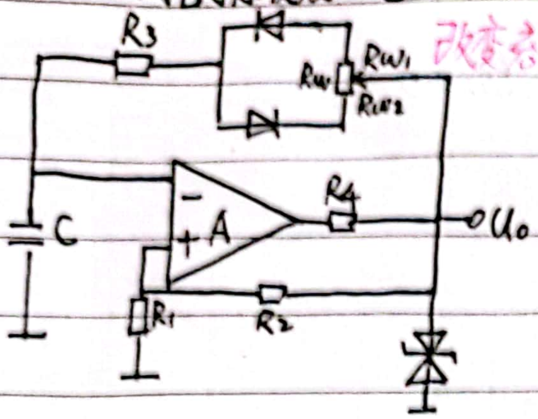
$$\Rightarrow -\frac{1}{R_3C}\cdot\frac{T}{2} = \ln\left(\frac{U_Z - U_T}{U_Z + U_T}\right)$$

$$T = 2R_3C\ln\left(\frac{U_Z + U_T}{U_Z - U_T}\right)$$

$$= 2R_3C\ln\left(1 + \frac{2U_T}{U_Z - U_T}\right)$$

$$= 2R_3C\ln\left(1 + \frac{2R_1}{R_2}\right)$$

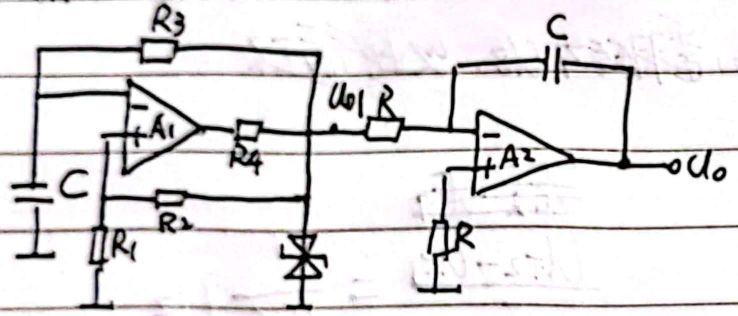
② 占空比可调的方波发生电路

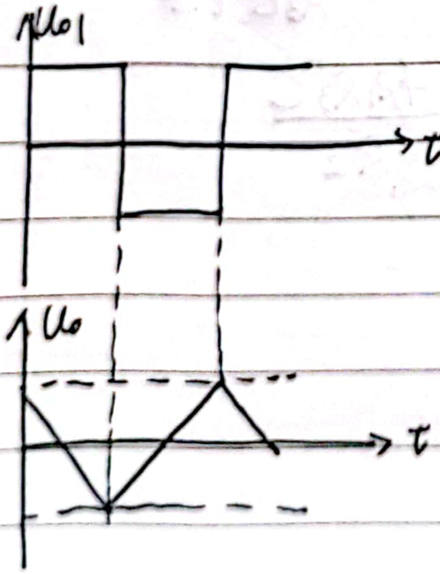


改变充放电的速度

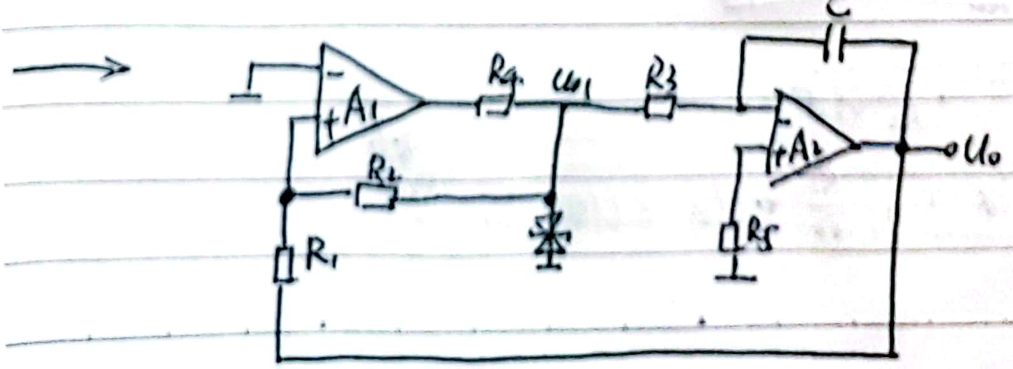
$$T=(2R_3+R_w)C\ln\left(1+\frac{2R_1}{R_2}\right)$$

③ 三角波发生电路 ☆☆☆





→可用作代替RC充电



当 $u_{O1}=+U_Z$ 时

$$u_{P1}=u_{O1}\cdot\frac{R_1}{R_1+R_2}+u_O\cdot\frac{R_2}{R_1+R_2}=u_{N1}=0$$

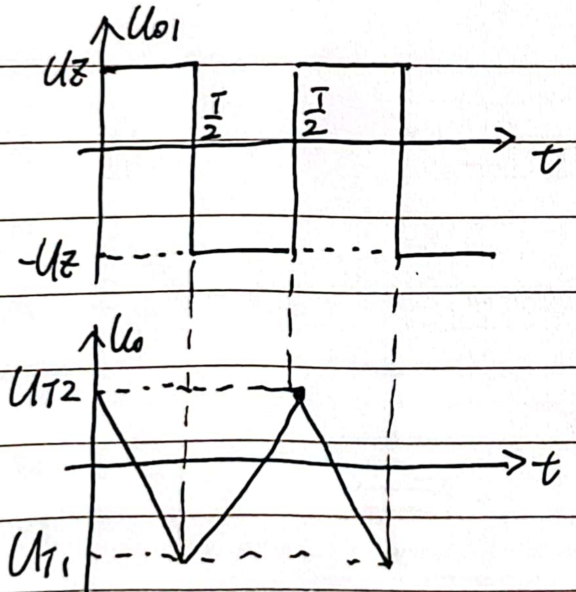
$$\Rightarrow U_{T1}=-\frac{R_1}{R_2}U_Z=u_O$$

当 $u_{O1}=-U_Z$ 时

$$U_{T2}=\frac{R_1}{R_2}U_Z=u_O$$

原理阐述

当 $u_{O1}=U_Z$ 时，u_{O1} 通过 R_3 给C充电，拉低了 u_O 电位，使 u_{P1} 电位下降，当 u_{P1} 电位小于0时，u_{O1} 翻转为 $-U_Z$，u_{O1} 通过 R_3 给C放电，拉高了 u_O 的电位，使 u_{P1} 电位上升，当 u_{P1} 大于0时，u_{O1} 翻转为 U_Z，以此循环



$U_{T2}-U_{T1}$

$$\frac{U_{T2}-U_{T1}}{\frac{T}{2}}=\frac{1}{R_3C}U_Z$$

$$\Rightarrow T=\frac{4R_1R_3C}{R_2}$$

$$u_O=U_Z+(U_{T2}-U_Z)e^{-\frac{t}{R_3C}}$$

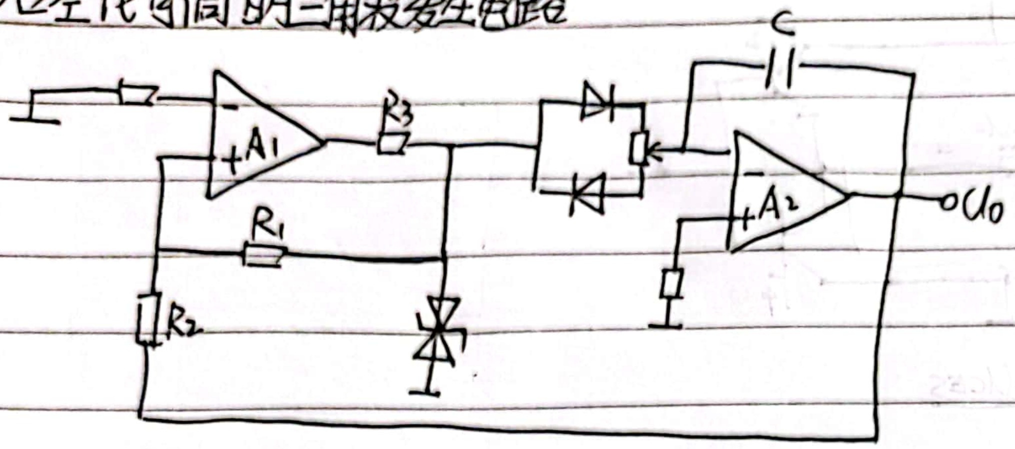
$$=U_Z+\left(\frac{R_1}{R_2}U_Z-U_Z\right)e^{-\frac{t}{R_3C}}$$

当 $t=\frac{T}{2}$ 时 $u_O=-\frac{R_1}{R_2}U_Z$

$$\Rightarrow -\frac{R_1}{R_2}U_Z=U_Z+\left(\frac{R_1}{R_2}U_Z-U_Z\right)e^{-\frac{T/2}{R_3C}}$$

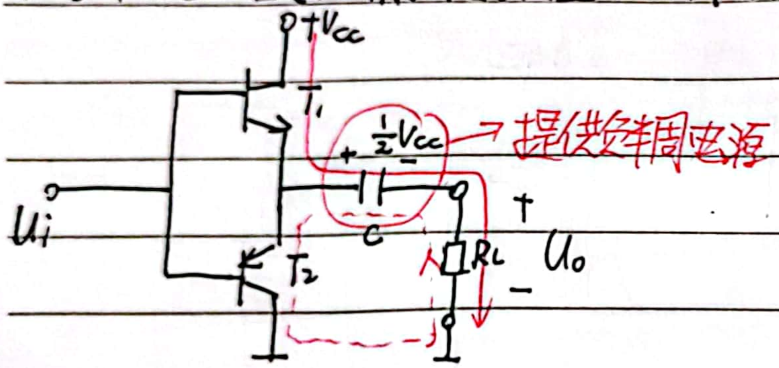
$T=$

④占空比可调的三角波发生电路



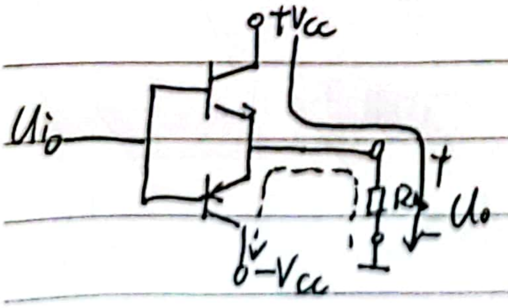
第八章：功率放大电路

1. OTL电路（无输出变压器的功率放大电路）



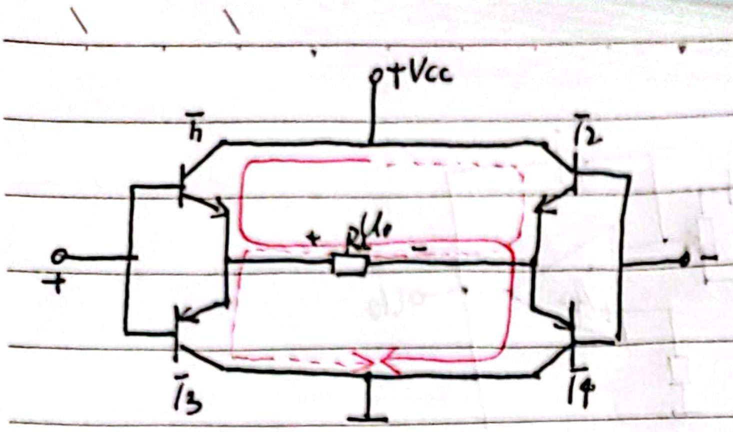
$$U_{om} = \frac{\frac{1}{2}V_{CC} - U_{CES}}{\sqrt{2}}$$

2. OCL电路（无输出电容的功率放大电路）



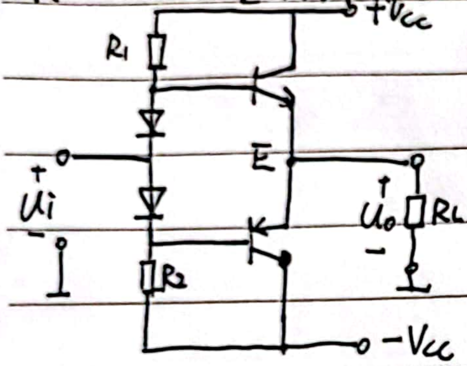
$$U_{om} = \frac{V_{CC} - U_{CES}}{\sqrt{2}}$$

3. BTL电路（桥式推挽功率放大电路）



$$U_{om}=\frac{V_{CC}-2U_{CES}}{\sqrt{2}}$$

4. OCL电路的计算☆☆☆



① $U_{om}=\frac{V_{CC}-U_{CES}}{\sqrt{2}}$

② $P_{om}=\frac{U_{om}^2}{R_L}=\frac{(V_{CC}-U_{CES})^2}{2R_L}$ 负载输出最大功率

③ $i_c=\frac{V_{CC}-U_{CES}}{R_L}\cdot\sin\omega t$

$$P_V=\frac{1}{\pi}\int_0^{\pi}\frac{V_{CC}-U_{CES}}{R_L}\sin\omega t\cdot V_{CC}\,d\omega t$$

$$=\frac{2}{\pi}\cdot\frac{V_{CC}(V_{CC}-U_{CES})}{R_L}$$ 电源消耗最大功率

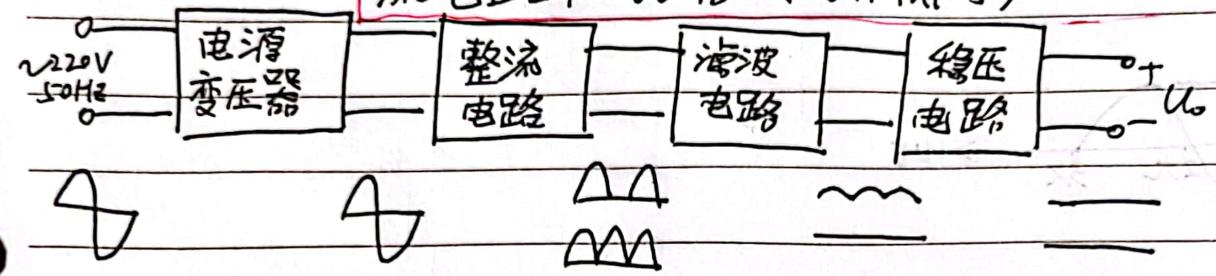
④ $\eta=\frac{P_{om}}{P_V}=\frac{\pi}{4}\cdot\frac{V_{CC}-U_{CES}}{V_{CC}}$ 转换效率

⑤ $P_T=\frac{1}{2\pi}\int_0^{\pi}(V_{CC}-U_{om}\sin\omega t)\frac{U_{om}}{R_L}\sin\omega t\,dt$

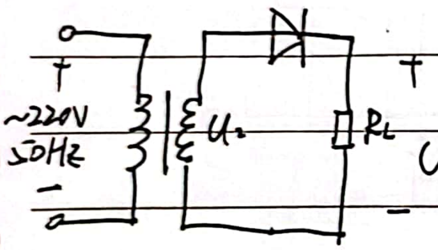
$$=\frac{1}{R_L}\left(\frac{V_{CC}U_{om}}{\pi}-\frac{U_{om}^2}{4}\right)$$

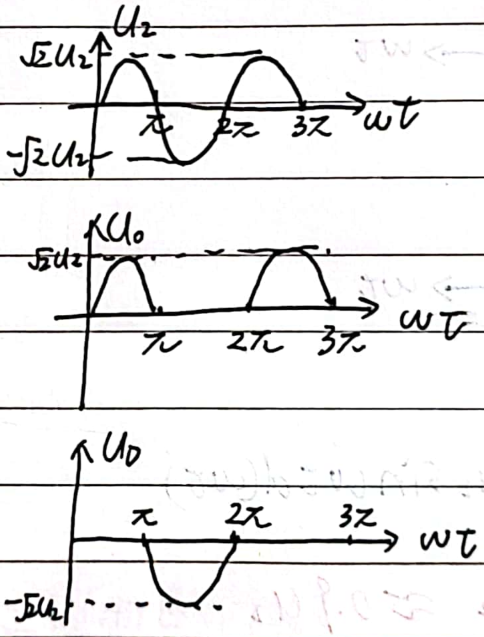
$P_{Tmax} = \frac{V_{CC}^2}{\pi^2 R_L}$ 三极管最大输出功率

第九章：直流电源 (不知道会考到什么程度，我自己看书学得也不好，感觉掌握整流电路和 W7800、W117即可)



1、单相半波整流电路





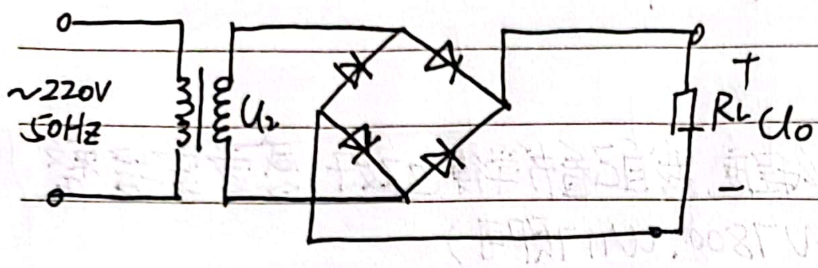
$$U_{O(AV)} = \frac{1}{2\pi}\int_0^{\pi} \sqrt{2}U_2 \sin\omega t \, d(\omega t)$$

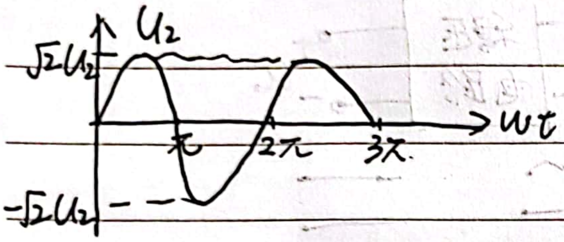
$$= \frac{\sqrt{2}U_2}{\pi} = 0.45U_2$$

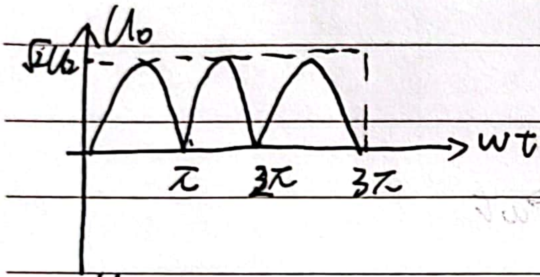
$$I_{O(AV)} = \frac{U_{O(AV)}}{R_L} = \frac{0.45U_2}{R_L}$$

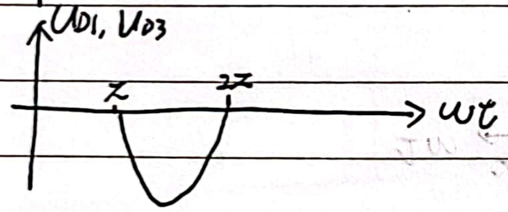
$$S = \frac{U_{OM}}{U_{O(AV)}} = \frac{U_2/\sqrt{2}}{\frac{\sqrt{2}U_2}{\pi}} = \frac{\pi}{2} \approx 1.57$$ (脉动系数)

2. 单相桥式整流电路







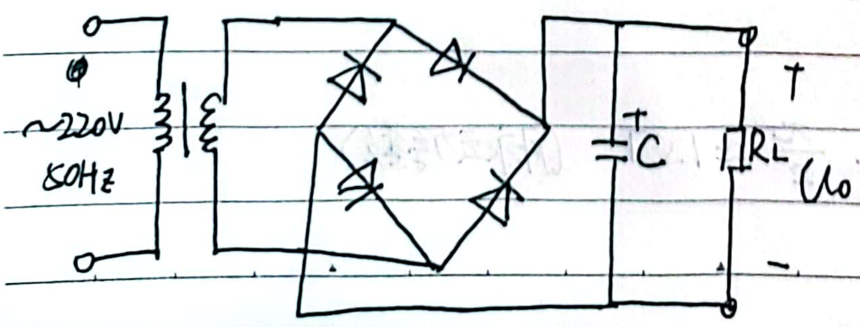


$$U_{o(AV)} = \frac{1}{\pi}\int_0^{\pi} \sqrt{2}U_2 \sin\omega t \, d(\omega t)$$

$$= \frac{2\sqrt{2}}{\pi}U_2 \approx 0.9U_2$$

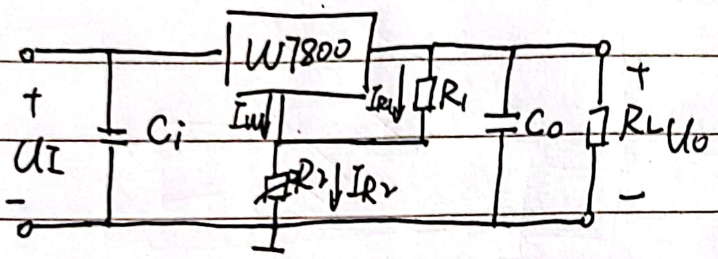
$$I_{o(AV)} \approx \frac{0.9U_2}{R_L}$$

3. 电容滤波电路（了解？）（后面内容偷懒没做了，而且看书也看不懂）



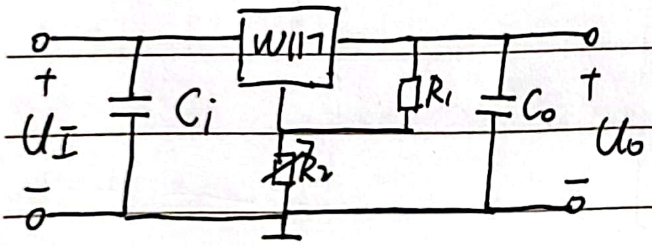
$$U_{o(AV)} = \sqrt{2}U_2(1-\frac{T}{4R_LC})$$

4、W7800的应用



$$U_o = U_o' + (\frac{U_o'}{R_1}+I_W)R_2$$ （U_o'是W7800输出，即R_1两端电压）

5. W117应用



$$U_o = (1+\frac{R_2}{R_1})\times 1.25V$$ （1.25V是W117的稳压输出，即R_1两端电压）

W7800与W117的区别：W117的I_W可以忽略